ROLE OF MRI IN STAGING OF ENDOMETRIAL CARCINOMA

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Dedicated

to

my Family

&

Teachers

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ABBREVIATIONS

ADC	Apparent diffusion coefficient
ADCmean	Mean apparent diffusion coefficient value
ADCmin	Minimum apparent diffusion coefficient value
BMI	Body mass index
CA	Carcinoma
CI	Confidence interval
CSI	Cervical stromal invasion
CT	Computed tomography
DCE	Dynamic contrast enhanced imaging
DVT	Deep venous thrombosis
DWI	Diffusion weighted imaging
EC	Endometrial carcinoma
FDG	18-Fluorodeoxyglucose
FIGO	International Federation of Gynecology and Obstetrics
FOV	Field of vision
FN	False negative
FP	False positive
G1	Grade 1
G2	Grade 2
G3	Grade 3
HNPCC	Hereditary nonpolyposis colorectal cancer
ITP	Idiopathic thrombocytopenic purpura
JZ	Junctional zone
LN	Lymph node
LVSI	Lymphovascular space invasion
MI	Myometrial invasion
MRI	Magnetic resonance imaging
NA	Not available
NOS	Not otherwise specified
NPV	Negative predictive value

p-value	Probability value
PET	Positron emission tomography
PPV	Positive predictive value
ROI	Region of interest
SD	Standard deviation
SI	Signal intensity
T	Tesla
T1WI	T1 weighted imaging
T2WI	T2 weighted imaging
T1 PC	T1 weighted post-contrast imaging
TSE	Turbo spin echo
TVUS	Transvaginal ultrasound
US	Ultrasound

ABSTRACT

INTRODUCTION: Endometrial cancer is the most common malignancy of female reproductive tract. The prognosis of patients depends on histologic grade, tumor stage including depth of myometrial invasion and lymph node status. Preoperative knowledge of these factors helps in planning treatment and tailoring the surgical approach.

AIM OF STUDY: 1. To stage endometrial carcinoma on MR imaging.

2. To assess the role of advanced MR imaging sequences (DCE and DWI) for the evaluation of myometrial invasion in patients with endometrial carcinoma.

3. To correlate the results with intra-operative findings and final histopathological examination wherever possible.

MATERIALS & METHODS: Thirty-six patients with biopsy proven endometrial carcinoma were enrolled in this prospective study. MRI was performed on 3 Tesla MRI using T1- and T2-WI, DWI and DCE imaging. Depth of myometrial invasion, lymph node metastasis and overall stage were assessed. The ADC values of the tumor were recorded. The MRI results were compared with post-operative histopathological analysis.

RESULTS: For assessing the depth of myometrial invasion, sensitivity, specificity and accuracy respectively, were as follows: T2WI - 70%, 75% and 73%; combined DWI + T2WI - 90%, 95% and 93%; combined DCE-MRI + T2WI - 90%, 90% and 90%. The overall accuracy of MRI in the staging of carcinoma endometrium was 86.7%. The mean (± SD) ADC values (10^{-3} mm^2/s) of intracavitary endometrial tumor (0.74 ± 0.12) and the myometrium at maximum depth of invasion (0.76 ± 0.09) were significantly lower than that of normal myometrium (1.32 ± 0.11). There was no significant difference between ADC values of endometrial carcinoma in patients with tumor G1 (0.74 ± 0.11), G2 (0.78 ± 0.15), or G3 (0.71 ± 0.06) ($p = 0.462$) and in patients with superficial (0.75 ± 0.13) and those with deep (0.72 ± 0.10) myometrial invasion.

CONCLUSION: MRI is an accurate imaging technique for the local staging of endometrial cancer and for evaluating the depth of myometrial invasion. DWI is equivalent to or slightly better than DCE-MRI and is particularly helpful in patients for whom contrast agents are contraindicated. ADC values help in the prediction of myometrial invasion of endometrial cancer, however, they do not correlate with histologic tumor grade and the depth of myometrial invasion.

KEYWORDS: Dynamic contrast enhanced MRI, Diffusion weighted imaging, Myometrial Invasion, Endometrial carcinoma, Local staging, Apparent diffusion coefficient.

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INTRODUCTION

Endometrial carcinoma is the fourth most common malignancy in females and the most common malignancy of the female reproductive tract worldwide.[1,2]

Most patients present with abnormal uterine bleeding (intermenstrual or postmenopausal). EC is more common during the 6th and 7th decades of life, with the mean age of 65 years.[3]

HISTOPATHOLOGY OF ENDOMETRIAL CARCINOMA

Endometrial carcinoma is divided into several histologic types; endometrioid adenocarcinoma is the most common accounting for 90% of the tumors. The other histologic types include adenocarcinoma with squamous cell differentiation, clear cell, papillary, serous, undifferentiated carcinoma and carcinosarcoma.[4,5]

Endometrioid adenocarcinomas are assigned a FIGO grade based on degree of glandular differentiation.

GX: Grade cannot be assessed.

G1: Well differentiated.

G2: Moderately differentiated.

G3: Poorly or undifferentiated.

Endometrial cancers have traditionally been classified in one of the following two categories:

Type I are the most common endometrial carcinomas. They include well or moderately differentiated (grade 1 and 2) endometrioid adenocarcinoma with minimal invasion of the myometrium and are associated with estrogen excess and obesity. These tumors often arise in the background of endometrial hyperplasia, occur in the early postmenopausal period, generally are low grade, and have a good prognosis.[6]

Type II endometrial carcinomas include poorly differentiated (grade 3) endometrioid, clear cell, serous papillary subtypes and carcinosarcomas/ mixed Mullerian tumors, which may cause deep myometrial invasion. They have no association with estrogen excess or

atypical hyperplasia, generally occur in older women and have a poorer prognosis.[7,8]

Histopathologic criteria for determining high-risk disease include high tumor grade (poorly differentiated), deep myometrial invasion (more than 50% myometrial thickness), lymphovascular space invasion (LVSI), non-endometrioid histology, and cervical stromal involvement.[9]

RISK FACTORS

Endometrial carcinoma is associated with lifestyle disorders presently epidemic world over, with obesity, hypertension, diabetes mellitus all associated with increased risk of malignancy. Other risk factors include prolonged estrogen exposure in form of early menarche or delayed menopause, nulliparity, old age, Stein Leventhal Syndrome, hormone replacement therapy, tamoxifen, and familial cancer syndromes such as HNPCC.[10]

PROGNOSTIC FACTORS IN CARCINOMA ENDOMETRIUM

Prognosis depends on a number of factors, including stage, depth of myometrial invasion, lymphovascular invasion, histologic grade, and lymph nodal status.[11,12] Depth of myometrial invasion is the single most important morphologic prognostic factor and correlates with tumor grade, presence of lymph node metastases, and overall patient survival.[13] With increasing myometrial penetration there is a progressive increase in the incidence of lymph node metastases from approximately 3% with superficial tumors to more than 40% with deep invasive tumors.[14] Consequently, preoperative information about the depth of myometrial invasion is essential in tailoring the surgical approach for these patients.

FIGO STAGING

Endometrial carcinoma is staged with the International Federation of Gynecology and Obstetrics (FIGO) system.[15,16] It was first proposed in 1988 and revised in 2009. The FIGO staging of endometrial cancer is surgical, requiring hysterectomy, bilateral salpingo-oophorectomy, pelvic and paraaortic lymph node dissection, peritoneal washings and omental biopsy for appropriate staging.[17]

Stage I endometrial carcinomas are confined to the uterine corpus. It is further divided into stages IA and IB. Stage IA tumors are confined to the endometrium or invade less than 50% of the myometrial thickness. Stage IB represents tumors with deep myometrial invasion (more than 50% of myometrial thickness).

Stage II tumors invade the stromal connective tissue of the cervix but do not extend beyond the uterus. Tumors with endocervical glandular invasion only are considered stage I.

Stage III represents a tumor with local or regional spread beyond the uterus, but not outside the true pelvis. It is further divided into stage IIIA which includes tumors that invade the uterine serosa and/or adnexa, stage IIIB which includes tumors with vaginal or parametrial involvement, and stage IIIC which includes tumors with spread to pelvic or para- aortic lymph nodes. Stage IIIC is further divided into stage IIIC1 when the tumor presents with pelvic lymph node involvement and stage IIIC2 when there is para- aortic lymph node involvement (with or without pelvic nodes).

Stage IV tumors are locally advanced or have distant metastases. It is further divided into stage IVA that includes tumors with extension to the bladder or bowel mucosa and stage IVB consisting of tumors that have distant metastases.[18]

The stage of endometrial carcinoma is closely related to treatment planning and patient survival and prognosis.[19] The mean 5-year survival rate for stage I is 85%, for stage II is 70%, for stage III is 50%, and for stage IV is 18%.[20]

Surgical staging is performed after an operation; thus, this system cannot provide useful information prior to surgery.[15,21] Therefore, there is a clinical need for noninvasive imaging modalities that can provide accurate preoperative staging information for endometrial carcinoma.

Table 1: Revised surgical FIGO staging (2009) of endometrial carcinoma with corresponding magnetic resonance imaging (MRI) findings.[15]

FIGO stage	Pathological findings	MRI findings
Stage I	Tumour confined to the corpus uteri	
IA	No or less than half myometrial invasion	The endometrial mass is confined to the endometrium or invades <50% of the myometrial wall with disruption of the JZ.
IB	Invasion equal to or more than half of the myometrium	Mass invades ≥50% of the myometrium with a preserved stripe of enhancing outer myometrial wall.
Stage II	Tumour invades cervical stroma, but does not extend beyond the uterus[a]	Disruption of the low-signal intensity inner cervical stroma (T2). Disruption of the cervical epithelium enhancement (CE T1).
Stage III	Local or regional spread of the tumour	
IIIA	Tumour invades the serosa of the corpus uteri and/or adnexae[b]	Disruption of continuity of the outer myometrium or presence of nodules on the peritoneal surface or adnexa.
IIIB	Vaginal and/or parametrial involvement	Tumour extension into upper vagina and/or parametrium.
IIIC	Metastases to pelvic and/or para-aortic lymph nodes	Enlarged pelvic and/or para-aortic lymph nodes (cut-off value: >10 mm for short-axis diameter).
IIIC1	Positive pelvic nodes	Enlarged pelvic lymph nodes.
IIIC2	Positive para-aortic lymph nodes with or without positive pelvic lymph nodes	Enlarged para-aortic lymph nodes.
Stage IV	Tumour invades bladder and/or bowel mucosa, and/or distant metastases	
IVA	Tumour invasion of bladder and/or bowel mucosa	Tumour extension into bladder/rectum with disruption of the hypointense signal of bladder or rectal wall.
IVB	Distant metastases, including intra-abdominal metastases and/or inguinal lymph nodes.	Intraperitoneal metastases in peritoneum or omentum. Distant (haematogenous) metastases to lung, bones or liver. Distant lymph node metastases.

CE T1, contrast enhanced T1-weighted imaging; FIGO, International Federation of Gynaecology and Obstetrics; JZ, junctional zone; T2, T2-weighted imaging.
[a] Exclusively endocervical glandular involvement should be considered stage I.
[b] Positive cytology should be reported separately without changing the stage.

TREATMENT OF ENDOMETRIAL CARCINOMA AND ROLE OF PRE-OPERATIVE IMAGING IN TREATMENT PLANNING

Stage I tumors are treated with transabdominal hysterectomy and bilateral salpingo-oophorectomy with peritoneal washings. Pelvic and para-aortic lymphadenectomy is not performed universally in stage I patients. It may be omitted in patients with low-grade tumors and stage IA disease as the added survival benefit of lymphadenectomy in these patients remains in doubt.[15] The incidence of lymph nodal metastases is approximately 4% in endometrioid adenocarcinoma grade 1 with superficial myometrial invasion as opposed to 30-45% in patients with grade 2,3 endometrial adenocarcinomas with deep myometrial invasion. Thus, presurgical staging helps to determine the extent of lymphadenectomy that should be performed and to reduce peri-operative and postoperative morbidity associated with lymph node resection based on tumor grade determined by endometrial curettage and myometrial invasion as determined by imaging.[22-24]

For endometrial cancers invading the cervical stroma (stage II), the standard surgical procedure is radical hysterectomy (removal of the uterus, cervix, upper vagina, parametrium, ovaries and fallopian tubes) followed by pelvic lymphadenectomy.

Stage III or IV carcinomas are managed on a case-to-case basis with surgical tumor resection including debulking of lymph node and other metastatic lesions, followed by chemotherapy and radiotherapy.[15]

Although endometrial carcinomas are most commonly diagnosed in postmenopausal patients, up to 35% are premenopausal women, and 3-14% of the cases are younger than 40 years. Uterus preserving surgery to preserve fertility may be a viable treatment option in some premenopausal patients without obvious myometrial invasion demonstrated confidently on preoperative imaging.[25] Though this is not the standard of care it may be considered in those patients who are highly motivated to preserve their fertility, have a low-grade tumor, are willing to accept the risks associated with deviation from the standard of care, and agree to a close follow-up schedule.[26]

IMAGING TECHNIQUES

Definitive diagnosis of endometrial carcinoma is generally made via endometrial biopsy or dilatation and curettage. However, this does not provide information regarding the locoregional spread of disease. The various imaging modalities used to evaluate endometrial carcinoma are described below –

1. **Ultrasound**

Transvaginal US is often the initial imaging examination for women with dysfunctional (postmenopausal or intermenstrual) uterine bleeding.[20] Endometrial carcinomas typically present as thickening of the endometrium. The sensitivity and specificity of transvaginal ultrasound for detecting endometrial carcinoma is approximately 96% and 61%, respectively, when an endometrial thickness threshold of 5 mm, in postmenopausal women, is used to define abnormal endometrial thickening.[27] Carcinoma is more likely when endometrium has a heterogenous echotexture with irregular and poor outline, while cystic changes are more common in endometrial hypertrophy, hyperplasia and polyps. Myometrial invasion is suggested when a mass disrupts the sub-endometrial halo or extends asymmetrically into the myometrium.[28] The sensitivity and specificity for TVUS in determining the depth of myometrial invasion are 69% and 70%, respectively.[20]

Limitations of TVUS include its operator dependence and limited field of view. In addition, there is insufficient data about the value of TVUS in predicting cervical extension, parametrial invasion, or lymphadenopathy.[29]

2. Computed Tomography

On contrast- enhanced CT, endometrial carcinoma appears as a hypoattenuating and hypoenhancing mass in the endometrial cavity. Poor soft-tissue differentiation of CT limits its use in the local staging of endometrial carcinoma. The sensitivity and specificity of CT in evaluating myometrial invasion range from 40% to 83% and from 42% to 75%, respectively.[30] Currently, CT is used mainly in the assessment of advanced disease, i.e., for staging patients with endometrial carcinoma by detecting nodal and distant metastases.

3. Positron Emission Tomography (PET)

PET-CT depends on the increased metabolic activity of malignant tissue resulting in increased uptake of 18-fluorodeoxyglucose [FDG]. Its role in local tumor staging is limited due to lack of spatial resolution. However, the modality has shown high sensitivity and specificity for predicting pelvic nodal involvement and distant metastatic disease. The sensitivity, specificity, and accuracy of PET/CT in the detection of lymph node metastases based on increased tracer uptake by the lymph node and independent of size were reported as 53%, 99%, and 98%, respectively.[31]

Fusion studies with PET-MRI have shown better anatomical resolution with better delineation of local tumor spread. It is a valuable technique for the assessment of the primary tumor and nodal staging in patients with endometrial cancer.[32] However, this method requires further evaluation in studies.

4. Magnetic Resonance Imaging (MRI)

Magnetic resonance imaging (MRI) provides anatomical and functional information about endometrial carcinoma and is playing an increasing role in clinical decisions regarding endometrial carcinoma due to its unique characteristics of non-invasiveness, high soft tissue resolution, and multiple imaging parameters. It is considered the most accurate

imaging modality for pre-treatment local staging of endometrial carcinoma.

MR IMAGING APPEARANCE OF CARCINOMA ENDOMETRIUM

On MRI, endometrial carcinoma is usually seen as a hypo- to-isointense mass on T1- weighted images (T1WI) and shows heterogenous intermediate signal intensity relative to hyperintense normal endometrium on T2- weighted images (T2WI).[5,33]

On dynamic post-contrast images, tumors show early enhancement compared to the normal endometrium, and slower enhancement than the myometrium.[34] The presence of uninterrupted enhancement of the subendometrial zone is best evaluated at approximately 25–60s after contrast injection.[35] The maximum contrast between hyperintense myometrium and hypointense endometrial tumor occurs 50–120 seconds after contrast medium administration, and this is the most important phase for accurate assessment of the depth of myometrial invasion.[36] Delayed phase images obtained after 3-4 minutes after contrast injection are useful in detecting cervical stromal invasion.[37]

Endometrial carcinoma exhibits impeded diffusion compared with surrounding tissue, manifesting with high signal intensity on high b-value diffusion-weighted MR images and low signal intensity on ADC maps.[38,39]

1. **Conventional MR Imaging**

T2-weighted images (T2WI) can be used to identify the depth of myometrial invasion. However, they often prove inadequate due to poor tumor-myometrium contrast, poor definition of the junctional zone particularly in postmenopausal patients, adenomyosis and leiomyomas that compromise accurate staging. Under these circumstances, DCE-MRI and DWI are of particular value.

2. **Dynamic Contrast Enhanced MR Imaging (DCE-MRI)**

DCE-MR imaging is a non-invasive method that allows the evaluation of tumor angiogenesis.[10]

DCE-MR enables qualitative and quantitative assessment of tumor status. Semi-quantitative evaluation of DCE-MR images is based on SI changes that can be evaluated using:

- SI curve
- The slope and height of enhancement curve (time-to-peak)
- Maximum SI (peak enhancement)
- Wash-in/ wash-out gradient.[10]

Post contrast images are beneficial in the detection of small tumors that may be difficult to define on T2WI. A limitation of this sequence is that some tumors may be isointense relative to the myometrium on the equilibrium phase.

3. Diffusion Weighted MR Imaging (DW-MRI)

DW-MRI is a functional imaging technique that displays information about the extent and direction of random water motion in tissues.[40]

DW images should always be reviewed with their corresponding ADC maps to avoid pitfalls such as T2 shine-through (apparent high signal intensity of a lesion due to the long T2).

ADC values are related to the proportion of extracellular and intracellular components within the tissue. Increased tissue cellularity or cell density decreases the ADC measurement. Thus, high ADCs suggest benign processes with low cellularity, whereas low ADCs indicate malignancy with large cell diameter and higher cell density, which restricts water diffusion. Therefore, ADC measurements can be valuable in differentiating benign from malignant lesions.[10]

It helps in better depiction of the primary tumor, increasing the detection of local extension in the cervix and skipping metastases to the vagina, and in diagnosing extrauterine spread to the peritoneum and lymph nodes.[41]

DWI is particularly useful in patients with nephrogenic systemic fibrosis or patients who have contraindication to intravenous injection of gadolinium-based contrast agents or have tumors that are isointense or hyperintense to the myometrium on contrast-enhanced images.[42,43]

DWI is also useful in evaluating the depth of myometrial invasion in the setting of concurrent adenomyosis.[44]

DEPTH OF MYOMETRIAL INVASION

The depth of MI is best measured on the axial oblique images acquired in a plane perpendicular to the endometrial cavity. First, a line is drawn parallel to the presumed inner edge of the myometrium. Then, two lines are drawn: one measuring the entire thickness of the myometrium and the other measuring the maximum tumor extension into the myometrium. The ratio of the two lengths corresponds to the depth of myometrial invasion.[45]

Pitfalls in accurate assessment of depth of myometrial invasion on MRI:

- Uterine involution in postmenopausal women causing thinning of myometrium.
- Large polypoidal tumor distending and thinning the myometrium.
- Involvement of cornua of the uterus where myometrium is physiologically thinner than elsewhere in the uterus.
- Endometrial tumor relatively isointense to myometrium on T2WI
- Distorted uterine anatomy by leiomyomas and/or adenomyosis.[45-47]

Diffusion-weighted and dynamic contrast enhanced MR imaging sequences have been shown to improve the accuracy of MR imaging in assessing the depth of myometrial invasion. The diagnostic accuracy of conventional MR imaging ranges from 55% to 77%.[36] Dynamic contrast-enhanced images, when read together with T2-weighted images, have a diagnostic accuracy of 85% to 98% for assessing myometrial invasion.[46] The diagnostic accuracy of diffusion-weighted MR imaging for assessing myometrial invasion ranges from 62% to 90%.[38]

CERVICAL STROMAL INVASION (CSI)

CSI is best assessed by evaluating both the sagittal and axial oblique images that are acquired parallel and perpendicular to the long axis of the cervix, respectively. On T2WI, CSI is seen as a disruption of the normal low signal intensity of the cervical stroma by intermediate signal

intensity of the tumor. On DCE-MRI, CSI is indicated when the normal enhancement of cervical stroma is disrupted by a hypoenhancing tumor. On DWI, CSI is suspected when high SI on high b value DWI and low SI on the ADC maps disrupts the low-SI cervical stroma.

The presence of tumor extension into the endocervical canal is not diagnostic of cervical stromal invasion. Cervical stroma must be disrupted to diagnose invasion. Direct cervical stroma invasion may occur without endocervical mucosa invasion in cases of adjacent myometrial invasion.[48,49]

LYMPH NODE METASTASIS

The risk factors for lymph node metastases in endometrial carcinoma include the presence of high-risk histologic subtypes (grade 3 endometrioid adenocarcinoma and non-endometrioid histologic types, i.e., carcinosarcoma, serous carcinoma or clear cell carcinoma), lymphovascular space invasion, deep myometrial invasion, and cervical stromal invasion.[50]

For discriminating between benign and malignant nodes, the most widely accepted criterion is nodal size (short-axis diameter of greater than 8 mm in pelvic nodes and 10 mm in para-aortic nodes).[15]

MRI has low sensitivity for detection of metastatic lymph nodes because MRI cannot discriminate between enlarged inflammatory lymph nodes and metastatic nodes and exhibits dissatisfactory diagnostic accuracy in cases of micrometastases.[35]

Other morphologic criteria to suggest metastatic involvement in smaller nodes include:

- Spherical shape
- Irregular contour or spiculated margins
- Central necrotic areas
- Heterogenous SI or SI similar to that of primary tumor on T2WI
- Enhancement pattern or ADC value similar to primary tumor
- Nodal group formation.[51]

DWI aids in the detection of lymph nodes owing to their high SI on high b-value images. However, there is a significant overlap between the

ADC values of benign and malignant nodes and therefore the technique is currently used only as an adjunct to T2WI.[52]

MR imaging can also allow accurate assessment of more advanced disease such as adnexal involvement, vaginal/ parametrial involvement, bladder / rectal invasion, and distant metastases.

PEARLS AND PITFALLS OF MRI IMAGING OF ENDOMETRIAL CARCINOMA [34]

Pearls

- Assessment of the depth of myometrial invasion is optimized by using both the sagittal and axial oblique planes.
- Dynamic multiphase contrast-enhanced imaging and DWI increase the accuracy of T2-weighted imaging for depicting the depth of myometrial invasion.
- Enhancement of cervical mucosa on delayed images (3-4 min) excludes cervical stromal invasion.
- Type 2 endometrial carcinoma may demonstrate a pattern of spread similar to that of ovarian carcinoma (with peritoneal metastases and serosal deposits).

Pitfalls

- Poor tumor-to-myometrium interface; polypoid tumor compresses the adjacent myometrium; adenomyosis and leiomyomas may cause the depth of myometrial invasion to be miscalculated at T2-weighted imaging. Avoid by correlating the depth of invasion with corresponding DWI findings.
- Inaccurate assessment of depth of myometrial invasion in the presence of cornual tumors because the myometrium is thin in the region of cornua.
- Overestimation of the depth of myometrial invasion on dynamic multiphase contrast-enhanced images because of peritumoral inflammation.

AIMS AND OBJECTIVES

1. To stage endometrial carcinoma on MR imaging.
2. To assess the role of advanced MR imaging sequences (DCE and DWI) for the evaluation of myometrial invasion in patients with endometrial carcinoma.
3. To correlate the results with intra-operative findings and final histopathological examination wherever possible.

REVIEW OF LITERATURE

Rockall et al. (2007) conducted a study to assess the diagnostic performance of T2-weighted and dynamic gadolinium-enhanced T1-weighted magnetic resonance imaging in the preoperative assessment of myometrial and cervical invasion by endometrial carcinoma and to identify imaging features that predict nodal metastases. Sensitivity and specificity for the detection of nodal metastases was 66% and 73%, respectively. The sensitivity for the identification of lymph node metastases using a size criterion of 10mm was low and the specificity dropped considerably if the size ‘‘cutoff’’ was decreased to 8 mm. The study concluded that MRI has a high sensitivity for detecting myometrial invasion and high specificity for detecting cervical invasion. Dynamic enhancement did not improve diagnostic performance.[53]

Shen et al. (2008) conducted a study to determine the feasibility of diffusion-weighted imaging (DWI) with a single-shot echo-planar sequence and parallel technique for depicting endometrial cancer and to examine the role of this technique in preoperative assessment. A total of 31 patients were recruited for MRI evaluation of suspicious endometrial lesions. The mean apparent diffusion coefficient of endometrial cancer was 0.864 x 10^{-3} mm^2/s and that of benign endometrial lesions was 1.277 x 10^{-3} mm^2/s. The diagnostic accuracy for myometrial invasion was 61.9% for DWI and 71.4% for gadolinium-enhanced T1-weighted 3D fat-suppressed spoiled gradient-recalled echo images. The study concluded that DWI can differentiate benign from malignant endometrial lesions. DWI also provides valuable information for preoperative evaluation and should be considered part of routine preoperative MRI evaluation for endometrial cancer.[54]

Lin et al. (2009) studied the diagnostic accuracy of fused T2-weighted and high-b-value diffusion-weighted magnetic resonance images at 3 T for evaluation of myometrial invasion in patients with endometrial cancer. The study included 48 patients with endometrial cancer for preoperative evaluation by using a 3-T MR. Two radiologists interpreted the depth of myometrial invasion on T2-weighted images,

dynamic contrast enhanced MR images, and fused T2-weighted and DW MR images. Surgical pathologic findings were the reference standard. For assessing any myometrial involvement, the addition of fused T2 + DWI to DCE or DCE + T2 was significantly better compared with DCE imaging alone or DCE + T2. Tumor apparent diffusion coefficients were 0.60–1.32 x 10^{-3} mm^2/sec (median, 0.75 x 10^{-3} mm^2/sec), with no significant correlation with the depth of myometrial invasion. The study concluded that fused T2-weighted and high-b-value DW images at 3 T can provide accurate information for preoperative evaluation of myometrial invasion.[38]

Sala et al. (2009) conducted a study to assess the added value of dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI) in predicting advanced stage disease in patients with endometrial carcinoma. The depth of myometrial invasion was correctly determined in 78% of the cases on T2WI alone, increasing to 92% with the addition of DCE-MRI. The addition of DCE-MRI led to the correct detection of deep myometrial invasion in all cases. Tumor extension to uterine cornu was the only variable significantly associated with incorrect estimation of the depth of myometrial invasion. The diagnostic performance of MRI in detecting lymph node metastasis was very high (100% sensitivity and 80% specificity for both T2W and T2W + DCE T1W). The study concluded that the addition of multiphase 3-dimensional DCE-MRI to T2WI can effectively assess the depth of myometrial invasion in endometrial carcinoma and may be a useful tool to guide the surgical approach.[45]

Hori et al. (2009) compared magnetic resonance imaging at 3.0 T and 1.5 T in the same patients for preoperative evaluation of endometrial carcinoma. The range of diagnostic accuracy, sensitivity and specificity of MRI for evaluation of lymph node metastases at 1.5 T and 3.0 T for two independent observers were 83 - 90%, 50 - 75% and 88 - 92% respectively. The study concluded that 3.0 T MRI is an equivalent imaging modality to 1.5 T imaging for presurgical evaluation of endometrial carcinoma, although not significantly superior to 1.5 T imaging.[55]

Rechichi et al. (2010) conducted a study to determine the diagnostic accuracy of diffusion weighted (DW) magnetic resonance imaging in the preoperative assessment of myometrial invasion by endometrial cancer. 47 patients with histologically confirmed endometrial cancer underwent preoperative MR imaging and postoperative histopathological findings served as a reference standard. In the assessment of tumor invasion, sensitivity, specificity, positive and negative predictive values of T2-weighted images were 92.3%, 76.5%, 60.0% and 96.3%, respectively. The corresponding values for dynamic images were 69.2%, 61.8%, 40.9% and 84.0%, and for DW images 84.6%, 70.6%, 52.4% and 92.3%. In conclusion, DW imaging proved to be accurate in assessing myometrial invasion, and it could replace dynamic imaging as an adjunct to routine T2-weighted imaging for preoperative evaluation of endometrial cancer.[56]

Zandrino et al. (2010) conducted a study on 30 patients to assess the diagnostic accuracy of magnetic resonance imaging in local staging of endometrial carcinoma and to review the results and pitfalls described in the literature. For deep myometrial infiltration, T2-weighted sequences reached a sensitivity of 85%, specificity of 76%, PPV of 73%, NPV of 87%, and accuracy of 80%, while contrast-enhanced scans reached a sensitivity of 90%, specificity of 80%, PPV of 82%, NPV of 89%, and accuracy of 85%. For cervical infiltration, T2-weighted sequences reached a sensitivity of 75%, specificity of 88%, PPV of 50%, NPV of 96%, and accuracy of 87%, while contrast-enhanced scans reached a sensitivity of 100%, specificity of 94%, PPV of 75%, NPV of 100%, and accuracy of 95%. The study concluded that unenhanced and dynamic gadolinium-enhanced magnetic resonance allows accurate assessment of myometrial and cervical infiltration. Information provided by magnetic resonance imaging can define prognosis and management.[57]

Rechichi et al. (2011) investigated the differences in ADC values of endometrial cancer from those of normal endometrium and myometrium and whether they vary according to histologic tumor grade, the depth of myometrial invasion, or lymph node status. The

mean (± SD) ADC value (10^{-3} mm^2/s) of endometrial cancer (0.77 ± 0.12) was significantly lower than that of normal endometrium (1.31 ± 0.11, $p < 0.0001$) and normal myometrium (1.52 ± 0.21, $p < 0.0001$). There was no significant difference between ADC values of endometrial cancer tissue in patients with tumor grade 1 (0.79 ± 0.08), grade 2 (0.76 ± 0.14), or grade 3 (0.75 ± 0.12) ($p = 0.67$); in patients with deep (0.77 ± 0.13) and those with superficial (0.76 ± 0.12) myometrial invasion ($p = 0.87$); and in patients with (0.78 ± 0.10) and those without (0.75 ± 0.14) lymph node metastases ($p = 0.64$). The study concluded that ADC values allow normal endometrium to be differentiated from endometrial carcinoma; however, they do not correlate with histologic tumor grade, the depth of myometrial invasion, or whether lymph node metastases are present.[58]

Bharwani et al. (2011) conducted a study to assess the use of DWI in the assessment of tumor grade in endometrial lesions. 42 endometrial lesions including 23 endometrial cancers and 19 benign lesions were evaluated with DW-MRI. Visual evaluation and the calculation of mean and minimum ADC values were performed and correlated with histology. There was no statistically significant difference between tumor grades. The mean ADC value of endometrial carcinoma (0.97 ± 0.31) was significantly lower than that of benign endometrial pathology (1.50 ± 0.14). The study concluded that tumor mean and minimum ADC values are not useful in differentiating histological tumor grade in endometrial carcinoma. However, mean ADC measurement can provide useful information in differentiating benign from malignant endometrial lesions. This information could be clinically relevant in those patients where pre-operative endometrial sampling is not possible.[59]

Beddy et al. (2012) compared the diagnostic performance of diffusion weighted magnetic resonance imaging with that of dynamic contrast enhanced MR imaging in evaluating the depth of myometrial invasion and overall stage in patients with endometrial cancer. This retrospective study was conducted on 48 women with endometrial carcinoma who underwent preoperative MR imaging. Two radiologists

independently interpreted the depth of myometrial invasion, overall stage, and presence of pitfalls associated with inaccurate assessment of myometrial invasion at T1- and T2-weighted imaging, DW MR imaging, and DCE MR imaging. The diagnostic accuracy, sensitivity and specificity for DW MR imaging was 90%, 84% and 100% and for DCE MR imaging was 71%, 61%, and 88% respectively. No association was found between inaccurate assessment of myometrial invasion and standard pitfalls with DW MR imaging. The study concluded that DW MR imaging has superior diagnostic accuracy in the assessment of myometrial invasion and significantly higher staging accuracy compared with DCE MR imaging. Known pitfalls in the assessment of myometrial invasion on MRI (leiomyoma, adenomyosis, poor tumour-myometrium contrast and loss of the junctional zone) did not affect the ability of readers to assess the degree of myometrial invasion with DWI.[44]

Zamani et al. (2012) conducted a study to investigate the diagnostic efficacy of pelvic MRI in determining the depth of myometrial invasion and cervical involvement in endometrial carcinoma and to compare the accuracy of pelvic MRI using the old and new FIGO staging systems in endometrial carcinoma. In the evaluation of deep tumoral invasion of the myometrium (>50%), sensitivity, specificity, diagnostic accuracy and positive and negative predictive values of MRI were 82.35%, 94.59%, 90.74%, 87.5% and 92.1%, respectively. For cervical stromal involvement, these values were 54.54%, 100%, 90.74%, 100% and 89.58%, respectively. The study concluded that using 2009 FIGO classification increases the accuracy of pelvic MR imaging for preoperative staging of patients with early stages of endometrial cancer.[60]

Nakamura et al. (2012) evaluated the correlation between ADCmin and the prognosis of patients with endometrial cancer. There were significant correlations between the ADCmin of the primary tumor and the FIGO stage, depth of myometrial invasion, cervical involvement, lymph node metastasis, ovarian metastasis, peritoneal cytology and tumor maximum size. The study concluded that a low preoperative

ADCmin of the primary tumor is an important predictive factor for identifying endometrial cancer patients with a risk of disease recurrence.[61]

Hori et al. (2013) conducted a study to assess the efficacy of 3-T magnetic resonance imaging using the three-dimensional turbo spin-echo T2-weighted and diffusion-weighted technique (3D-TSE/DW) compared with that of conventional imaging using the two-dimensional turbo spin-echo T2- weighted and dynamic contrast-enhanced technique (2DTSE/DCE) for the preoperative staging of endometrial cancer, with pathological analysis as the reference standard. 71 women with endometrial cancer were included in the study. The accuracy, sensitivity and specificity, respectively for assessing deep myometrial invasion were: 3D-TSE/DW—observer 1, 87%, 95% and 85%; observer 2, 92%, 84% and 94%; 2DTSE/DCE—observer 1, 80%, 79% and 81%; observer 2, 86%, 84% and 87%. Most of the values were higher with 3D-TSE/DW without significant differences (P>0.12). The study concluded that the accuracy of 3D-TSE/DW was at least equivalent to that of the conventional technique for the preoperative assessment of endometrial cancer.[62]

Andreano et al. (2014) compared the diagnostic accuracy of dynamic contrast-enhanced and diffusion-weighted MR imaging in detecting deep myometrial invasion in endometrial cancer, using surgical-pathological staging as a reference standard. A meta-analysis of nine studies in 442 patients was done. The pooled sensitivity of DW and DCE was 0.86 and specificity did not significantly differ between the two sequences (DW = 0.86 and DCE = 0.82). The meta-analysis concluded that MR imaging has high sensitivity and specificity in evaluating deep myometrial invasion and that they did not vary significantly between DWI and DCE imaging and thus DWI can be used as an alternative to contrast enhanced imaging for evaluation of myometrial invasion.[63]

Zheng L et al. (2015) compared dynamic contrast-enhanced magnetic resonance imaging with T2-weighted imaging for the preoperative staging of early endometrial carcinoma. This retrospective study

included 22 subjects with early endometrial carcinoma who underwent 3.0 T MRI examination prior to hysterectomy. Revised International Federation of Gynecology and Obstetrics surgical staging guidelines (2009) were used as the reference standard. The sensitivity, specificity, PPV, NPV, and accuracy of DCE-MRI for preoperative staging were 100%, 62.5%, 82.4%, 100% and 86.4% and those for T2WI were 85.7%, 75%, 85.7%, 75% and 81.8% respectively. The study concluded that DCE-MRI is more sensitive but less specific than T2WI for the preoperative staging of early endometrial carcinoma. DCE-MRI can serve as a useful and reliable tool for the preoperative assessment of endometrial carcinoma.[19]

Mourad et al. (2016) evaluated the accuracy of combined T2 and diffusion weighted images in comparison to combined T2WI and dynamic contrast-enhanced magnetic resonance imaging for assessment of the depth of myometrial invasion. 62 patients diagnosed pathologically with endometrial carcinoma were included in the study. The pathological diagnosis was used as a gold standard for comparison with imaging. Diagnostic accuracy, sensitivity, specificity of combined T2/DWI were 92%, 90% and 95.6% while for combined T2/DCE were 79%, 77% and 82.6% for myometrial invasion <50%. The diagnostic accuracy, sensitivity, specificity of combined T2/DWI were 92%, 95.6% and 90% while the combined T2/DCE were 79%, 82.6% and 77% for myometrial invasion >50%. The study concluded that combined T2WI-DWI has superior diagnostic accuracy compared to combined T2WI-DCE-MRI in the assessment of depth of myometrial invasion in endometrial cancer. T2WI-DWI can eliminate contrast material injection especially for patients who cannot tolerate contrast administration.[64]

Kececi et al. (2016) conducted a study to evaluate the efficacy of diffusion-weighted imaging in differentiating between benign and malignant endometrial lesions and determining tumor grade, also in detection of myometrial invasion depth in malignant lesions. The lesions were classified as benign or malignant according to the histopathological results and, the mean apparent diffusion coefficient

(ADC) values were compared. For determining the myometrial invasion depth of malignant lesions, T2W, DWI and dynamic contrast-enhanced T1-weighted images (DCET1WI) were evaluated individually. The sensitivity, specificity and area under the curve for discriminating between malignant and benign lesions by using cutoff ADC value of 1.10×10^{-3} s/mm^2 were 85.7%, 92.8% and 0.95, respectively. According to the histopathological grading, there was no difference in the mean ADC values. The diagnostic accuracy of MRI in determining the depth of myometrial invasion in malignant lesions was found to be 87.1%, 89.7% and 76.9%, 76.9% for T2WI-DWI and DCET1WI, respectively. The study concluded that DWI and ADC measurements can accurately discriminate endometrial cavity lesions as benign or malignant. T2WI-DWI is highly effective in determining the depth of myometrial invasion.[65]

Shrivastava et al. (2016) studied the characteristic MRI findings in the pre-operative staging of endometrial carcinomas and compared it with the newly revised FIGO staging scheme of 2009 based on post-operative surgical histopathology. Majority of the patients (61%) were between the age group of 41-60 years. Most of the patients (72%) were postmenopausal at the time of presentation. Most common histopathology of endometrial carcinoma was endometroid adenocarcinoma (75%). FIGO staging of 12 patients (85.7%) showed concordance with MRI Staging for Stage Ia, with up-gradation of two patients to Stage Ib. The study concluded that information provided by MRI can define prognosis and help planning the surgical approach.[66]

Takeuchi et al. (2017) compared the diagnostic ability of reduced field-of-vision (FOV) diffusion-weighted (DW) magnetic resonance imaging with that of three-dimensional (3D) dynamic contrast-enhanced MR imaging in evaluating the depth of myometrial invasion in patients with endometrial cancer. 25 women with surgically proven endometrial cancer were retrospectively evaluated. The depth of myometrial invasion on MR imaging was correlated with surgical pathology results. The depth of myometrial invasion could be accurately evaluated in 68% of the cases for T2-weighted imaging, 92% for DCE MR imaging, and

96% for reduced FOV DW imaging. The study concluded that the addition of reduced FOV DW imaging may improve the staging accuracy of MR imaging for endometrial cancer in assessing the depth of myometrial invasion. Especially, reduced FOV DW imaging has an advantage in assessing the depth of myometrial invasion for patients with coexisting adenomyosis. Reduced FOV DW imaging can be an alternative to DCE MR imaging in evaluating the myometrial invasion of endometrial cancer without the use of contrast medium.[67]

Thieme et al. (2018) compared the diagnostic performance of diffusion-weighted and dynamic contrast-enhanced imaging and volumetric analyses in the preoperative assessment of myometrial invasion in patients with endometrial carcinoma. DWI and DCE showed a sensitivity and specificity in evaluating the depth of myometrial invasion of 92% and 96% and 92% and 86%, respectively. The study concluded that DWI and DCE are both good diagnostic tools for the preoperative assessment of myometrial invasion and there is potential for omitting gadolinium-based contrast agents given the high diagnostic value of DWI.[68]

Bonatti et al. (2018) evaluated the ability of MRI in predicting the histological grade of endometrial cancer (EC). This was a retrospective study on 90 patients with histologically proven EC who underwent preoperative MRI and surgery. Myometrial invasion (</>50%) was assessed. ADC maps were generated and MRI parameters were compared with the definitive histological grade. Deep myometrial invasion was significantly more frequent in G2-G3 lesions than in G1 ($p < 0.005$). ADC values didn't show any statistically significant correlation with tumor grade and the study concluded that ADC values are not useful for predicting EC grade.[69]

Yan et al. (2018) conducted a study to explore the use of ADC values in differentiating the preoperative tumor grading of endometrioid adenocarcinomas and investigate the relationship between the ADC values of endometrial cancer and the histological tumor subtype. The mean ADC values for high-grade endometrioid adenocarcinomas were significantly lower than the values for low-grade tumors (0.800 vs

0.962×10^{-3} mm^2/s). However, no significant differences in ADCmean and ADCmin values were found between tumor grades (G1, G2, and G3) of endometrial cancer. The study concluded that ADCmean was useful for identifying high-grade and low-grade endometrioid adenocarcinomas.[70]

Deng et al. (2018) investigated the diagnostic value of ADC of the peritumoral zone for assessing the infiltration depth of endometrial cancer. The peritumoral zone was defined as a 5-mm-thick zone surrounding and adjacent to the cancerous endometrium. The ADCmean values of tumors and peritumoral zones were 0.83×10^{-3} mm^2/sec and 1.06×10^{-3} mm^2/sec, respectively. There was no significant difference between the ADCmean values of the tumors in the superficial and deep myometrial invasion groups ($P > 0.05$). However, the ADCmean value at the peritumoral zone in the deep myometrial invasion group (1.23×10^{-3} mm^2/sec) significantly differed from that in the superficial myometrial invasion group (0.99×10^{-3} mm^2/sec) ($p = 0.005$). The study concluded that ADCmean at the peritumoral zone can predict deep myometrial invasion of endometrial cancer.[71]

Keriakos et al. (2018) conducted a study to assess the ability of DWI in the detection, characterization and staging of uterine tumors. DWIs with ADC maps showed a sensitivity and specificity of 80% in endometrial cancers. The mean ADC value for endometrial cancers was $0.8 \times 10^{-3} mm^2/s$. The study concluded that conventional MRI findings in conjunction with DWI and quantitative measurement of the ADC are effective methods in the diagnosis and staging of uterine cancer.[72]

Gil et al. (2019) studied 44 patients with endometrial carcinoma to evaluate the added value of diffusion-weighted imaging in the preoperative assessment of myometrial invasion in endometrial cancer, in comparison with T2-weighted imaging and dynamic contrast-enhanced magnetic resonance imaging. Consensus interpretation of depth of myometrial invasion and the stage of endometrial cancer was performed by two radiologists, considering three sets of sequences:

T2WI, DCE-MRI+T2WI and DWI+T2WI. DWI+T2WI demonstrated better diagnostic performance in assessing deep myometrial invasion than did DCE-MRI+T2WI and T2WI and the difference was statistically significant in comparison with T2WI ($p < 0.05$) but not in comparison with DCE-MRI+T2WI ($p > 0.05$). The study concluded that the addition of DWI apparently improves the diagnostic accuracy of MRI in the preoperative assessment of the depth of myometrial invasion in endometrial cancer, which may be particularly helpful in patients for whom contrast agents are contraindicated.[73]

MATERIALS AND METHODS

SOURCE OF DATA

It was a prospective study on patients of biopsy proven endometrial carcinoma referred for pelvic MRI to the Department of Radio-diagnosis, Dayanand Medical College and Hospital, Ludhiana over a period of 1.5 years from 1st November 2018 to 30th April 2020.

METHOD OF COLLECTION OF DATA

Thirty-six female patients with diagnosed endometrial carcinoma on histopathology were included in the study.

MRI was performed after fulfilling the following inclusion and exclusion criteria.

INCLUSION CRITERIA

- All patients with biopsy proven endometrial carcinoma**.**

EXCLUSION CRITERIA

- Any contraindications to MRI (cardiac pacemakers, prosthetic heart valves, cochlear implants, or claustrophobia).
- Any contraindications to contrast administration (estimated glomerular filtration rate < 30 ml/min/1.73m^2 in patients undergoing DCE MR Imaging).
- Patients who do not consent to be a part of the study.

PREPARATION OF PATIENT

Written informed consent was obtained from each patient and relevant detailed history was elicited. Articles such as jewellery, keys, credit cards, watches, coins, and other metallic objects were placed in the provided locker facility. The procedure was explained to the patient in her vernacular language to allay the fear and anxiety. Patient was placed in supine position and had a partially filled bladder. During the entire period of procedure, the patient was in contact with the technician/doctor by a two-way intercom system.

MAGNETIC RESONANCE IMAGING PROTOCOL:

All patients underwent a multiplanar, multi sequential MRI scan of the pelvis on a MAGNETOM SKYRA 48 Channel 3 Tesla MR Machine by Siemens, Germany.

All patients underwent axial T1-weighted, large FOV, axial T2-weighted and sagittal T2-weighted turbo spin echo (TSE) sequences. Thin slice (3mm) axial and coronal oblique T2 weighted TSE sequences (obtained in a plane perpendicular and parallel to the endometrial cavity) were then performed. Axial diffusion weighted images (DWI) were obtained with three b-values (50, 400, 800) and high b values (1400-1600) reconstructed using extrapolation. Dynamic contrast-enhanced study was performed after intravenous injection of gadobenate dimeglumine, Multihance, 0.1 mmol/kg administered as a rapid bolus intravenous injection followed by a manual 20 mL saline flush. DCE images were acquired in the sagittal plane using three-dimensional gradient echo sequence, followed by axial oblique images using post-contrast turbo spin-echo sequence and a delayed sagittal T1 gradient echo sequence to assess the cervical invasion.

Table 2: MRI Sequence Parameters

Sequences	Localizer	T2 Sagittal	T1 Axial	T2 Axial	T1 Fat sat Axial	T2 Coronal	DWI	DCE	T1 PC Axial	T1 PC Sagittal
Acquisition Time	0:25	3:29	2:55	2:47	3:25	2:44	3:22	0:15	3:25	3:35
Orientation	Trans Versal	Sagittal	Axial	Axial	Axial	Coronal	Axial	Axial	Axial	Sagittal
Resolution Matrix	179 x 256	269 x 384	256 x 320	269 x 384	224 x 320	269 x 384	114 x 114	195 x 320	224 x 32	224 x 320
Number of Slices	9	25	25	25	25	25	25	80	25	25
FoV Read (mm)	420	230	220	220	220	230	220	350	220	220
FoV Phase (%)	100	100	100	100	100	100	100	81.3	100	100
Slice Thickness (mm)	7.0	3.0	3.0	3.0	3.0	3.0	3.0	1.2	3.5	3.5
Slice Gap (mm)	7.0	3.1	2.1	2.1	2.1	2.1	2.1	20%	2.4	2.8
Repetition Time (msec)	1000	2800	680	3100	60	2800	4000	3.42	600	630
Echo Time (msec)	89	87	18	89	20	87	64	1.24	20	20
Flip Angle (deg)	160	180	154	180	160	175	-	9	160	160
Fat Suppression	None	None	None	None	Fat sat	None	SPAIR	Q-fat sat	Fat sat	Fat sat
Flow Compensation	No	No	Read	Slice	No	No	-	-	No	No

MR IMAGE ANALYSIS

The MR images were evaluated for the depth of myometrial invasion (<50% or >50%), cervical stromal invasion, invasion of serosa, adnexa, parametrium and adjacent organs (bladder, bowel) and for lymph node metastasis.

1. Evaluation of MR Images for myometrial invasion

Depth of myometrial invasion was evaluated on T2 weighted images, combined T2WI + DWI, combined T2WI + DCE-MRI and combined T2 + DWI + DCE-MR images.

a) **T2 weighted images:** On T2 weighted images, myometrial invasion was recorded when there was loss of the low T2 signal of the junctional zone and inhomogeneity of the adjacent myometrium.

b) **Diffusion weighted images:** For assessment of diffusion restriction, the signal intensity within the mass at high b-value DW images and ADC maps was evaluated. High signal intensity on high b-value DW images with a corresponding low signal on ADC maps was regarded as restricted diffusion.

   Mean ADC values were measured by placing circular regions of interest (ROIs) (5-9 mm^2 size). Three ROIs were drawn: in the intracavitary endometrial tumor, at the maximum depth of myometrial invasion and in normal myometrium. The ROIs were placed on the T2WI and then manually copied to the corresponding ADC map, whereupon ADC values were automatically calculated. The placement of ROIs is shown in figure 1.

c) **Dynamic contrast enhanced MR images:** On DCE, interruption of the normal subendometrial enhancement by hypoenhancing tumor on early DCE images was considered suggestive of myometrial invasion.

   Irregularity of the tumor-myometrial interface on any sequence (T2WI, DCE, DWI) was also considered suggestive of myometrial invasion.

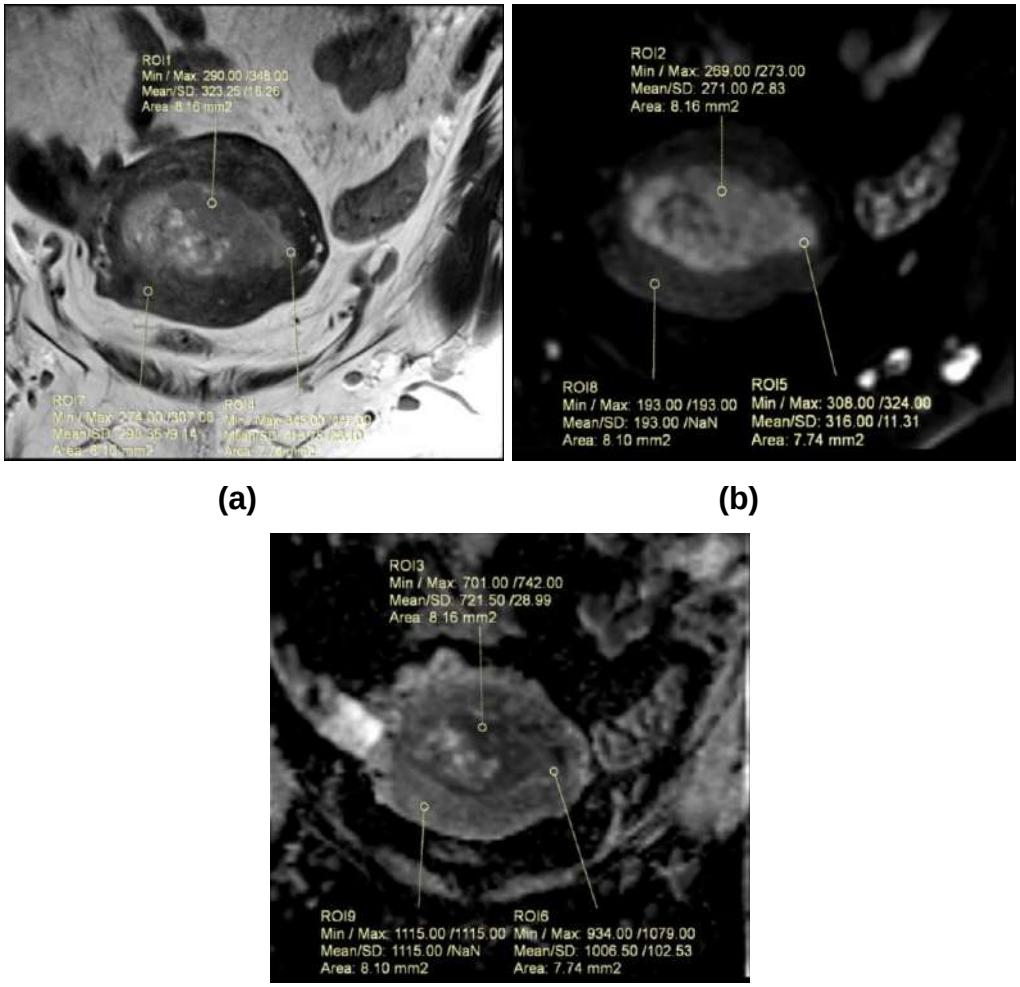
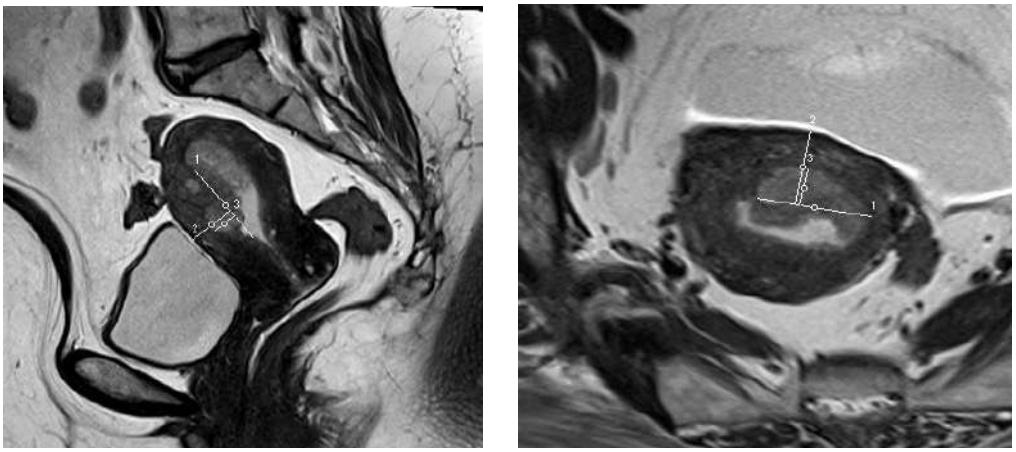


Figure 1: ROI placement for quantitative ADC value

(a) Axial oblique T2-WI, **(b)** DWI and **(c)** ADC images show placement of ROIs in the intracavitary tumor (top), myometrium at maximum depth of invasion (bottom right) and in normal myometrium (bottom left).

Determining the depth of myometrial invasion

For determining the depth of myometrial invasion, a line was drawn parallel to the presumed inner edge of the myometrium. Then, two perpendicular lines were drawn: one measuring the thickness of the entire myometrium, the other measuring the maximum tumor extent into the myometrium. The ratio of the two lengths corresponds to the depth of myometrial invasion. Deep myometrial invasion was diagnosed when the tumor involved ≥50% of the myometrial wall thickness.



(a) **(b)**

Figure 2: Measurement of depth of myometrial invasion

(a) Sagittal T2-WI and **(b)** Axial oblique T2-WI show measurement of depth of myometrial invasion. Line 1 is drawn parallel to the presumed inner edge of myometrium. Then, lines 2 and 3 are drawn perpendicular to line 1 measuring the thickness of the entire myometrium and the maximum tumor extent into the myometrium respectively. The percentage depth of myometrial invasion = 3/2 x 100.

2. **Evaluation of MR images for cervical invasion**

Cervical stromal invasion was diagnosed when there was disruption of the normal low signal intensity of the cervical stroma by intermediate signal intensity tumor on T2 weighted images, disruption of normal enhancement of cervical stroma by hypoenhancing tumor on delayed phase DCE images and diffusion restriction on DWI.

3. **Evaluation of MR images for serosal, adnexal, and visceral invasion**

Serosal invasion was diagnosed when intermediate-to-high signal intensity lesion disrupts the normally smooth outer contour of the uterus on T2 weighted images. Soft tissue mass invading the ovaries with diffusion restriction was considered suggestive of adnexal invasion. Visceral invasion was diagnosed as direct invasion of the bladder or rectal mucosa by the tumor with loss of intervening fat planes.

4. Evaluation of MR images for lymph node metastasis

Lymph nodes were evaluated for shape, margins, size, signal intensity and necrosis.

Round shape, irregular margins, short-axis diameter >8mm, intermediate signal intensity on T2 weighted images and central necrosis were recorded as positive signs for metastatic nodal involvement.

Lymph nodes with oblong shape, regular margins, short-axis diameter ≤ 8mm, homogenous T2 signal and no necrosis were considered reactive/normal.

After surgical treatment of carcinoma with hysterectomy ± local resection, the correlation of MRI findings was done with intra-operative findings and the histopathology report.

STATISTICAL ANALYSIS:

Data was described in terms of range; mean ± standard deviation (± SD), median, frequencies (number of cases) and relative frequencies (percentages) as appropriate. Sensitivity, specificity, positive and negative predictive values and accuracy of each MR sequence and their confidence interval (95% CI) were also calculated. The accuracy of the different sets of sequences in the evaluation of deep myometrial invasion was compared with p-value adjustment by the Benjamini-Hochberg procedure for controlling the false discovery rate in multiple comparisons. Results were analyzed using Wilcoxon ranked test and Kruskal-Wallis test for comparison of continuous variables. A probability value (*p*-value) less than 0.05 was considered statistically significant. All statistical calculations were done using SPSS (Statistical Package for the Social Science) SPSS 21 version statistical program for Microsoft Windows.

OBSERVATIONS AND RESULTS

1. DEMOGRAPHIC AND CLINICAL DATA

a) Age distribution of patients

The study was conducted on 36 patients with biopsy proven endometrial carcinoma (Table 3). The age range of patients was 35 - 88 years with mean age of 61 years. Maximum patients in our study (n=16, 44.4%) were between 61-70 years of age (Figure 3).

Maximum number of patients in our study (n=33, 91%) were post-menopausal, 2 (5.6%) patients were pre-menopausal while 1 (2.8%) patient was peri-menopausal (Table 4, Figure 4).

Table 3: Age distribution of patients

Age (years)	No. of cases	Percentage
< 50	4	11.1%
51-60	14	38.9%
61-70	16	44.4%
> 70	2	5.6%
Total	36	100.0%

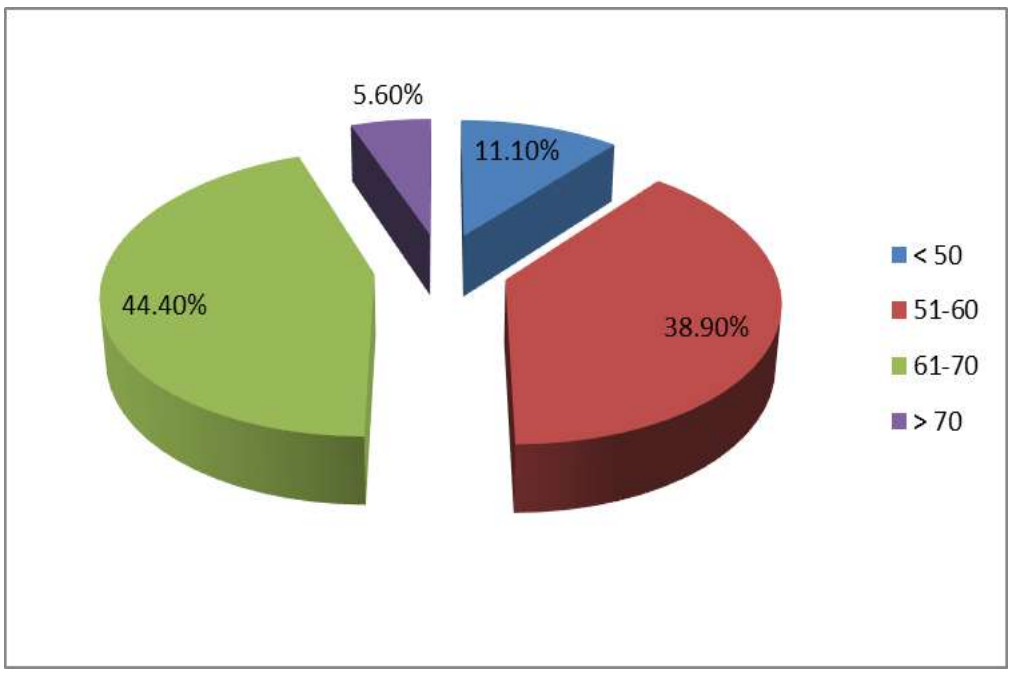


Figure 3: Age distribution of patients

Table 4: Menopausal status of patients

Menopausal status	No. of cases	Percentage
Pre-menopausal	2	5.6%
Peri-menopausal	1	2.8%
Post-menopausal	33	91.7%
Total	36	100.0%

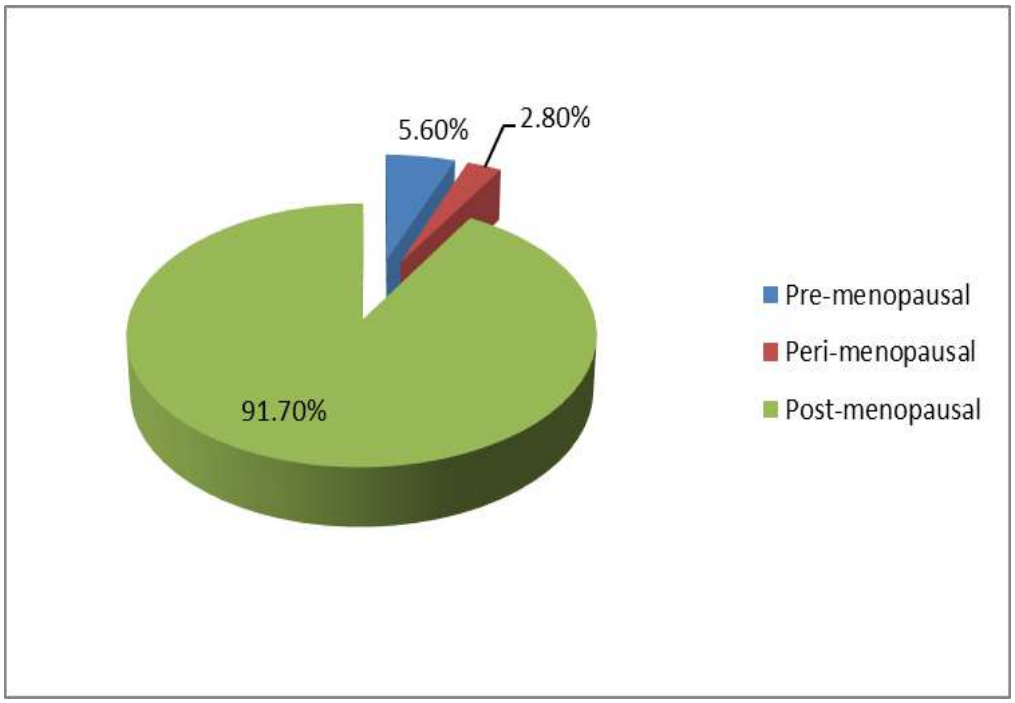


Figure 4: Menopausal status of patients

b) Clinical symptoms

The most common presenting symptom was post-menopausal bleeding (n=32, 88.9%). Patients in the pre- and peri-menopausal age group presented with abnormal vaginal bleeding (n=3, 8.3%) while one (2.8%) post-menopausal patient was incidentally detected with endometrial mass during ultrasound abdomen done for urinary tract infection (Table 5, Figure 5).

Table 5: Distribution of patients according to clinical symptoms

Clinical symptoms	No. of cases	Percentage
Post-menopausal bleeding	32	88.9%
Abnormal vaginal bleeding	3	8.3%
Incidentally detected	1	2.8%
Total	36	100.0%

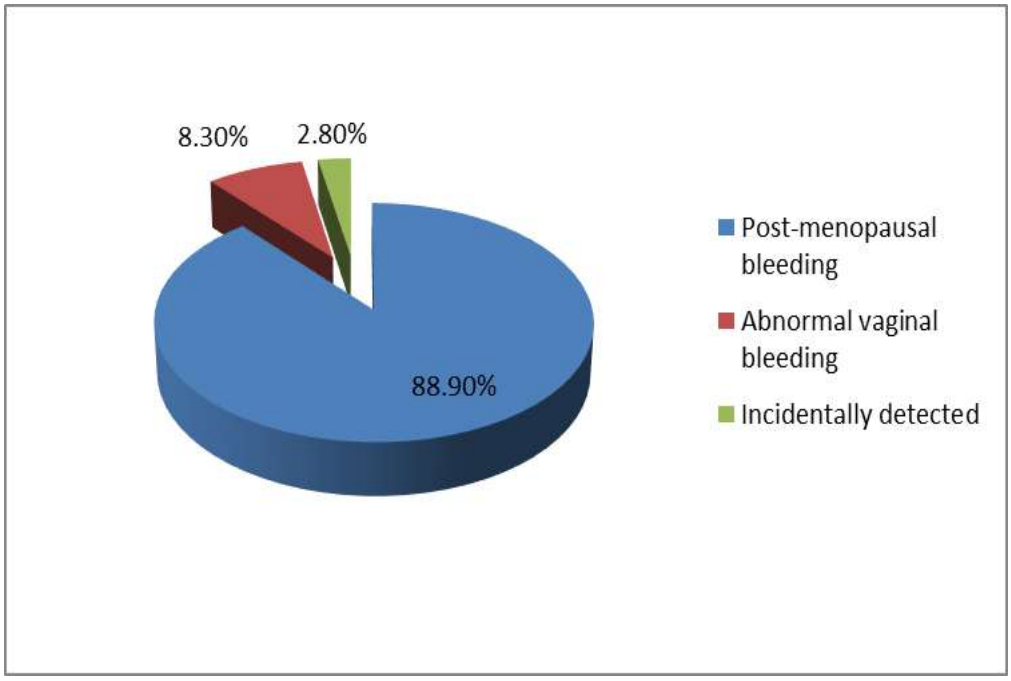


Figure 5: Distribution of patients according to clinical symptoms

c) Body Mass Index (BMI) of patients

16.7% (n=6) patients in our study had BMI less than 25, 50% (n=18) patients had BMI in the range of 26-30, while 33.3% (n=12) patients had BMI of more than 30 (Table 6, Figure 6).

Table 6: Distribution of patients according to Body mass index

BMI	No. of cases	Percentage
< 25 (Normal)	6	16.7%
26-30 (Overweight)	18	50.0%
> 30 (Obese)	12	33.3%
Total	36	100.0%

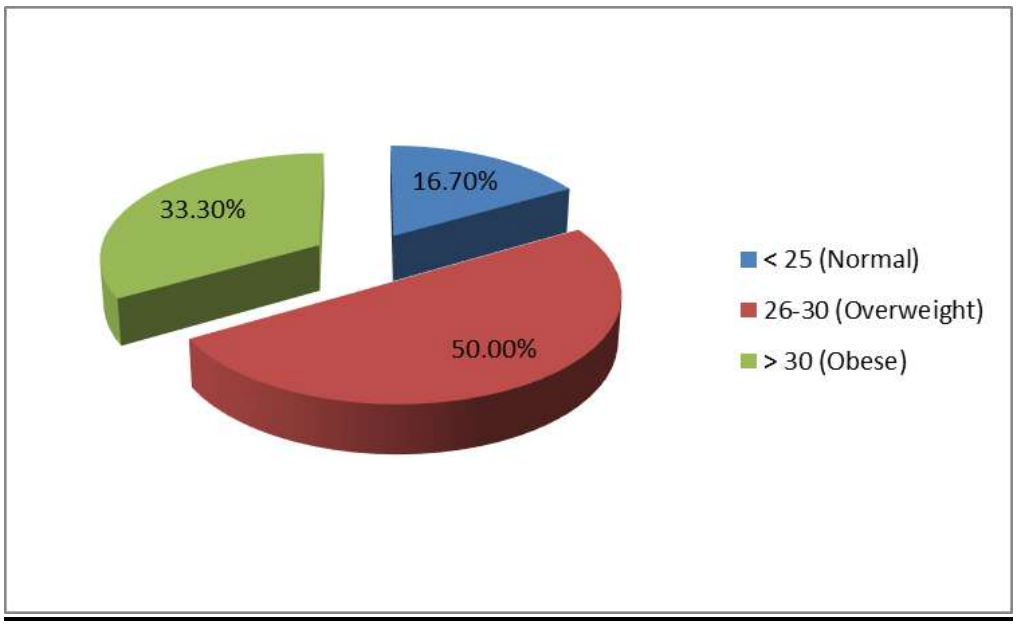


Figure 6: Distribution of patients according to BMI

d) Associated co-morbidities

Many patients in our study had multiple co-morbidities.

Hypertension as an associated co-morbidity was seen in 63.9% (n=23) patients, diabetes mellitus in 33.3% (n=12) patients and hypothyroidism in 19.4% (n=7) patients (Table 7, Figure 7).

Table 7: Associated co-morbidities

Co-morbidities	No. of cases	Percentage
Hypertension	23	63.9%
Diabetes	12	33.3%
Hypothyroidism	7	19.4%
Bronchial asthma	1	2.8%
CA ascending colon	1	2.8%
Cirrhosis	1	2.8%
DVT left lower limb	1	2.8%
CA Breast	1	2.8%
ITP	1	2.8%
Migraine	1	2.8%
Rheumatoid arthritis	1	2.8%

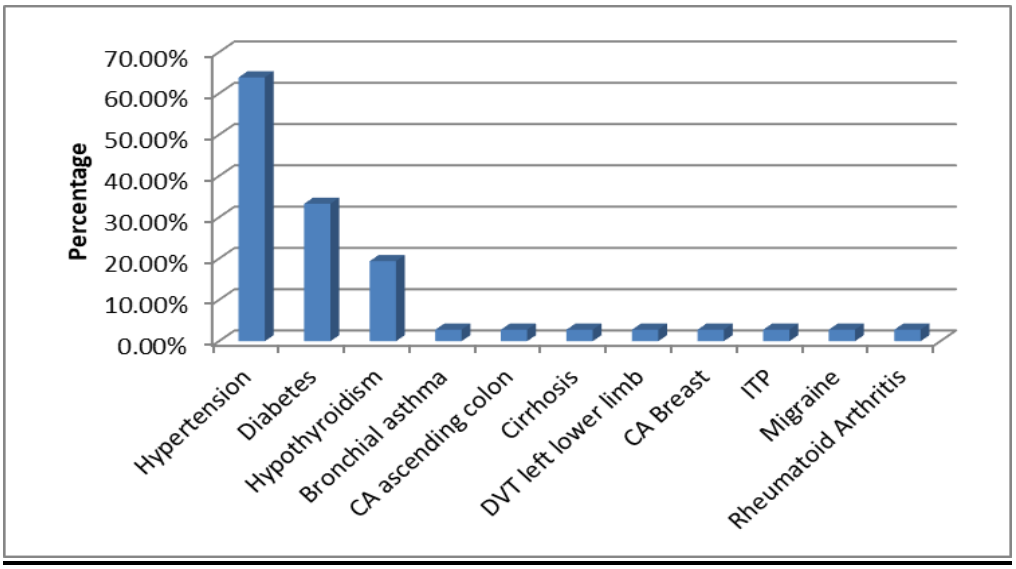


Figure 7: Associated co-morbidities in patients with carcinoma endometrium

2. ULTRASONOGRAPHIC APPEARANCE OF TUMOR

Endometrial thickness on Ultrasound

The cut-off value for abnormal endometrial thickening on ultrasound in post-menopausal patients was taken as 5mm. The range of endometrial thickness on ultrasound varied from 8mm to 76mm (Table 8).

Table 8: Endometrial thickness on ultrasound

	Menopausal Status				Total
Endometrial thickness (mm)	**Post-menopausal**		**Pre-menopausal**		
6-10mm	3	9.00%	0	0.00%	3
11-20 mm	14	42.40%	1	33.30%	15
> 20 mm	16	48.50%	2	66.70%	18
Total	33	100.00%	3	100.00%	36

3. HISTOPATHOLOGICAL TYPE AND GRADE OF ENDOMETRIAL CARCINOMA

a) Histopathological type of tumor

On pre-imaging histopathology, endometrioid adenocarcinoma was seen in 80.6% (n=29) cases. There were 4 (11.1%) cases of carcinosarcoma, 2 (5.6%) cases of adenocarcinoma, NOS (not otherwise specified) and 1 (2.8%) case of papillary adenocarcinoma (Table 9, Figure 8).

Table 9: Histopathological type of tumor

Histopathological type	No. of cases	Percentage
Endometrioid adenocarcinoma	29	80.6%
Carcinosarcoma	4	11.1%
Adenocarcinoma, NOS (not otherwise specified)	2	5.6%
Papillary adenocarcinoma	1	2.8%
Total	36	100.0%

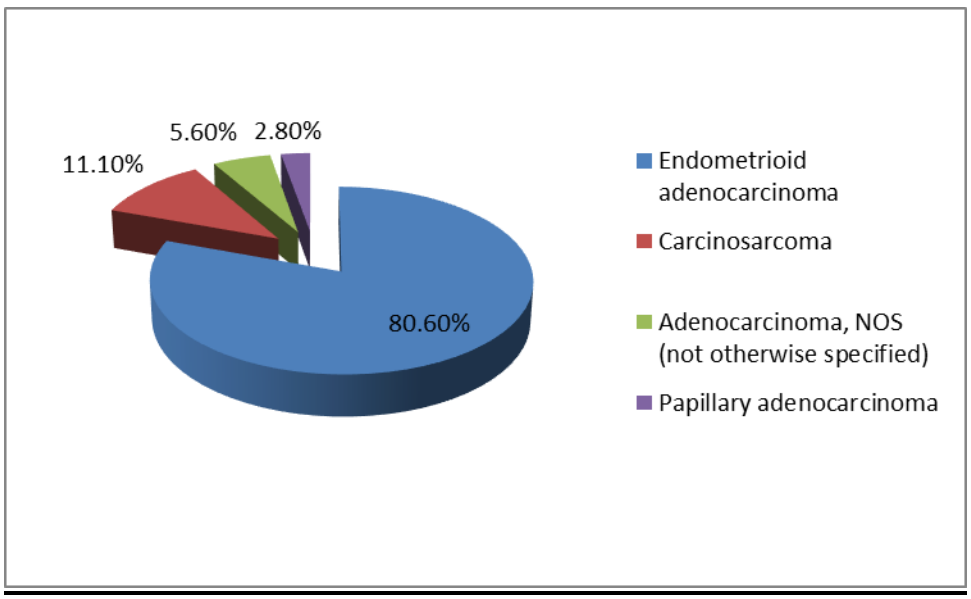


Figure 8: Histopathological subtype of tumor

b) FIGO Grade of Endometrioid adenocarcinoma

51.7% (n=15) cases of endometrioid adenocarcinoma were well differentiated type (grade 1), 41.4% (n=12) cases were moderately differentiated (grade 2) and 6.9% (n=2) were poorly differentiated (grade 3) (Table 10, Figure 9).

Table 10: FIGO Grade of endometrioid adenocarcinoma

Grade	No. of cases	Percentage
Grade 1	15	51.7%
Grade 2	12	41.4%
Grade 3	2	6.9%
Total	29	100.0%

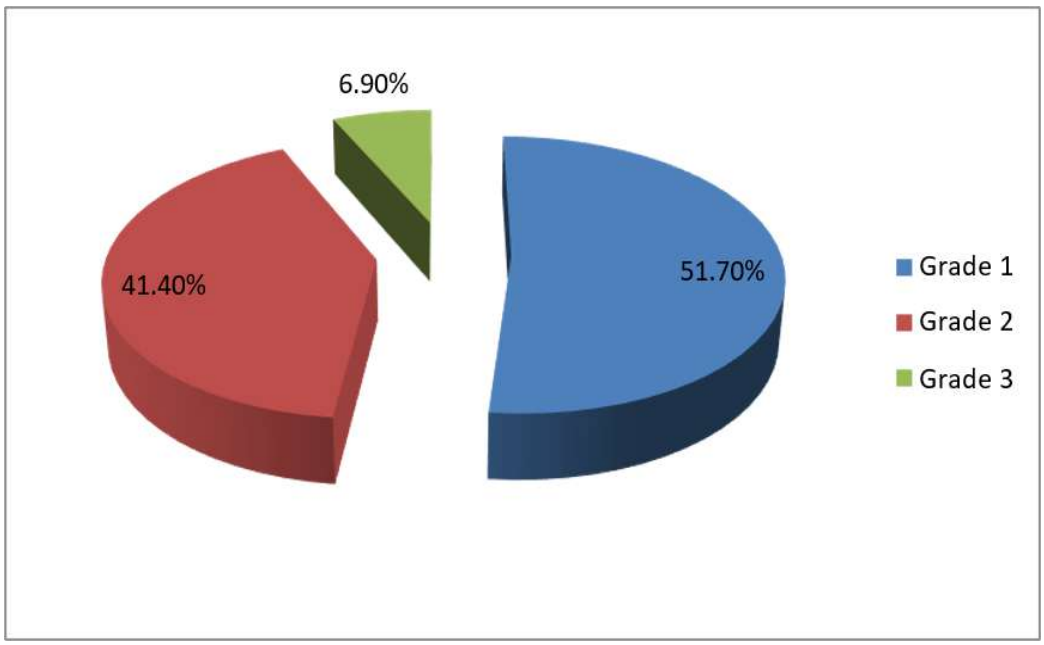


Figure 9: Histopathological FIGO grade of endometrioid carcinoma

4. MRI FINDINGS

a) MR imaging appearance of tumor

In 80.6% (n=29) cases, endometrial carcinoma was of intermediate signal intensity on T2WI, while mixed and heterogenous signal was seen in 19.4% (n=7) cases (Table 11, Figure 10).

Table 11: Signal intensity on T2 weighted images

Signal on T2WI	No. of cases	Percentage
Intermediate	29	80.6%
Mixed and heterogeneous	7	19.4%
Total	36	100.0%

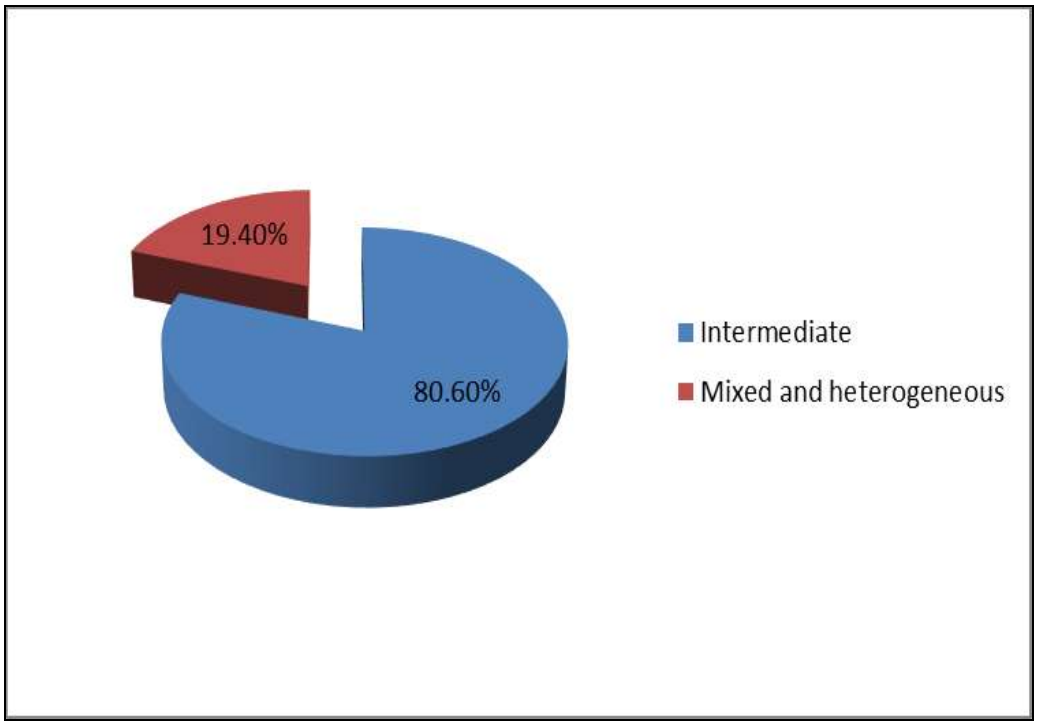


Figure 10: Tumor signal intensity on T2 weighted MR images

In all (n=36) the cases, the tumor was bright on diffusion weighted images with hypointense signal on corresponding ADC maps. The ADC values of the endometrial carcinoma range between 0.42 - 0.98 x 10^{-3} mm^2/sec with mean ADC of 0.74 ± 0.12 x 10^{-3} mm^2/sec.

On dynamic contrast enhanced MR images, the tumor was hypoenhancing as compared to the normal myometrium in 77.8% (n=28) cases. Heterogenous enhancement was seen in 7 (19.4%) cases. Avid early enhancement was seen in one (2.8%) case due to associated endometrial polyp (Table 12, Figure 11).

Table 12: Enhancement pattern on Dynamic contrast enhanced images

Enhancement pattern on DCE	No. of cases	Percentage
Hypo-enhancing	28	77.8%
Heterogenous enhancement	7	19.4%
Avid early enhancement	1	2.8%
Total	36	100.0%

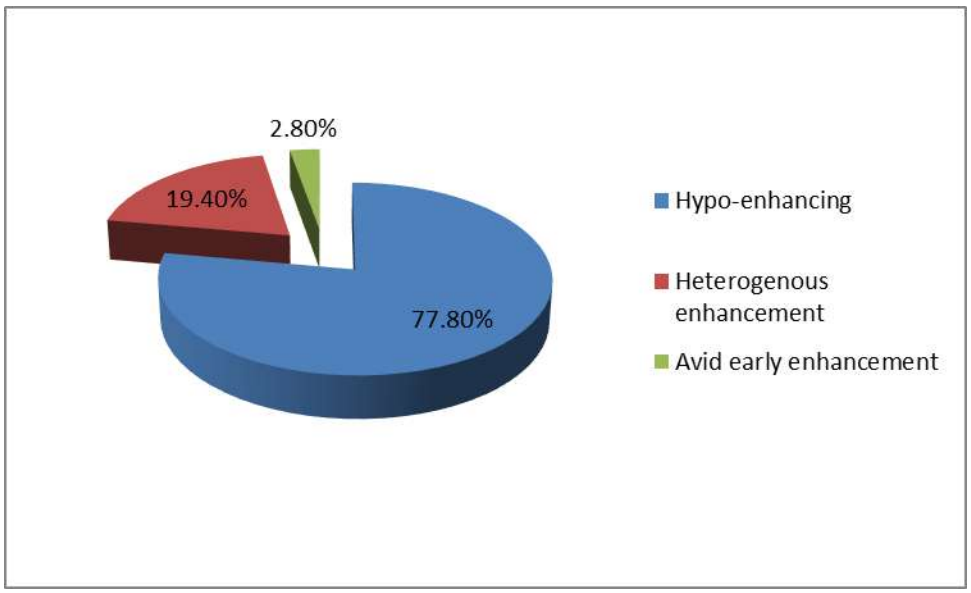


Figure 11: Enhancement pattern on DCE-MRI

b) Depth of myometrial invasion on MRI

Out of total 36 patients who underwent MRI for pre-operative staging, 18 (50%) patients had less than 50% myometrial invasion and 18 (50%) had more than 50% myometrial invasion on T2WI.

On combined DWI + T2WI, 20 (55.6%) patients had superficial myometrial invasion and 16 (44.4%) patients had deep myometrial invasion.

Combined DCE-MRI + T2WI showed less than 50% myometrial invasion in 19 (52.8%) patients and more than 50% invasion in 17 (47.2%) patients.

On combined T2WI + DWI + DCE-MRI, 20 (55.6%) patients had superficial myometrial invasion and 16 (44.4%) patients had deep myometrial invasion (Table 13, Figure 12).

Table 13: Depth of myometrial invasion on MRI

Percentage of myometrial invasion	T2WI		DWI + T2WI		DCE-MRI + T2WI		T2WI + DWI + DCE-MRI	
	No. of Cases	Percentage	No. of Cases	Percentage	No. of Cases	Percentage	No. of Cases	Percentage
< 50%	18	50.0%	20	55.6%	19	52.8%	20	55.6%
> 50%	18	50.0%	16	44.4%	17	47.2%	16	44.4%
Total	36	100.0%	36	100.0%	36	100.0%	36	100.0%

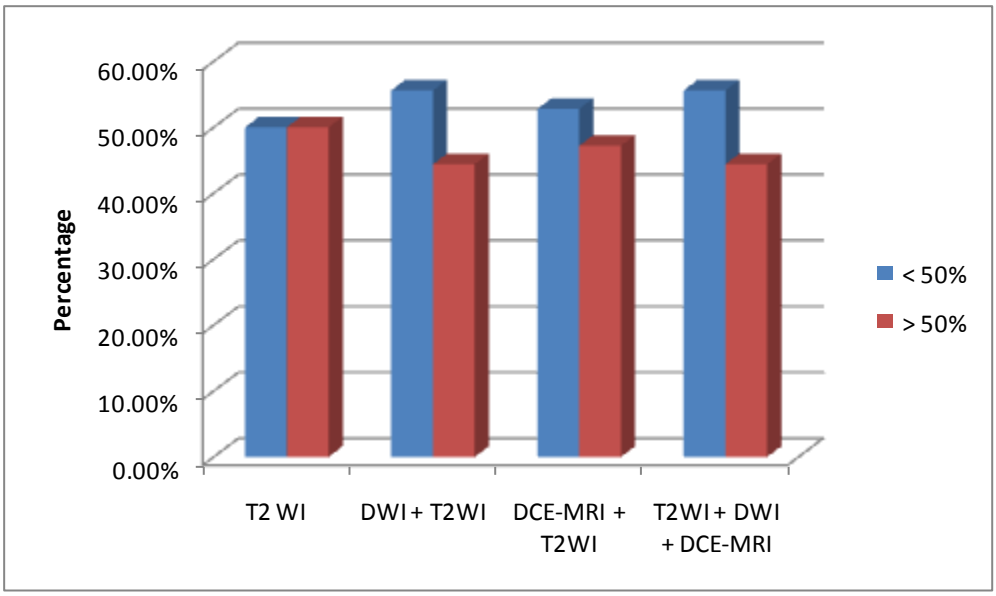


Figure 12: Depth of myometrial invasion on MRI

c) Local and regional spread of tumor

Out of 36 patients, invasion of cervical stroma was seen in 4 (11.1%) patients.

Serosal extension of the tumor was present in 4 (11.1%) patients, adnexal invasion in 2 (5.6%) and visceral invasion in 2(5.6%) patients.

None of the patients in our study showed parametrial invasion (Table 14).

Table 14: Local and regional spread of tumor

Local and regional spread	Cervical invasion		Serosal invasion		Adnexal invasion		Parametrial invasion		Visceral invasion	
	No. of Cases	%	No. of Cases	%	No. of Cases	%	No. of Cases	%	No. of Cases	%
Yes	4	11.1%	4	11.1%	2	5.6%	0	0.0%	2	5.6%
No	32	88.9%	32	88.9%	34	94.4%	36	100.0%	34	94.4%
Total	36	100.0%	36	100.0%	36	100.0%	36	100.0%	36	100.0%

d) Lymph nodes evaluation on MRI

In 11.1% (n=4) patients, lymph nodes were enlarged with round shape, irregular margins, and intermediate signal on T2 weighted images. These lymph nodes were considered suspicious for metastasis.

5.6% (n=2) patients had large lymph nodes masses with lobulated outline, intermediate T2 signal and central necrotic areas suggestive of metastatic involvement.

Oblong but enlarged (10mm and 11mm in short axis) lymph nodes were seen in 5.6% (n=2) patients. These lymph nodes showed homogenous signal on T2 with regular margins and no evidence of necrosis. These were considered reactive as there were no other findings suspicious for metastatic involvement.

In most of the cases (n=28, 77.7%), lymph nodes were normal in size with oblong shape, regular margins, homogenous T2 signal and no necrosis. These lymph nodes were considered reactive/normal (Table 15).

Table 15: Evaluation of lymph nodes on MRI

Shape	Margins	Size (short axis)	Signal intensity on T2	Necrosis	Number	Percentage
Round	Irregular	>8mm	Intermediate	No	4	11.1%
Lymph nodal mass	Lobulated	>8mm	Intermediate	Yes	2	5.6%
Oblong	Regular	>8mm	Homogenous	No	2	5.6%
Oblong	Regular	≤8mm	Homogenous	No	28	77.7%
Total					36	100.0%

e) Associated uterine fibroids and adenomyosis

Out of total 36 patients with endometrial carcinoma, 17 (47.2%) patients had associated fibroids (Table 16).

Adenomyosis was present in 7 (19.4%) patients (Table 17).

Table 16: Associated uterine fibroids

Fibroids	No. of cases	Percentage
No	19	52.8%
Yes	17	47.2%
Total	36	100.0%

Table 17: Associated adenomyosis

Adenomyosis	No. of cases	Percentage
No	29	80.6%
Yes	7	19.4%
Total	36	100.0%

f) Incidental adnexal findings

The incidental adnexal findings detected in our study were hematosalpinx, hydrosalpinx, tubo-ovarian abscess, ovarian fibromas and ovarian endometrioma in one (2.8%) patient each and simple ovarian cysts in 2 (5.6%) patients (Table 18).

Table 18: Incidental adnexal findings

Adnexal findings	**No. of cases**	**Percentage**
Hematosalpinx	1	2.8%
Hydrosalpinx	1	2.8%
Tubo-ovarian abscess	1	2.8%
Ovarian fibromas	1	2.8%
Ovarian endometrioma	1	2.8%
Simple ovarian cyst	2	5.6%
None	29	80.6%
Total	36	100.0%

g) MRI FIGO Stage

In our study, out of 36 patients, 19 (52.8%) were staged as FIGO Ia, 10 (27.8%) patients were staged as FIGO Ib, 5 (13.9%) patients as stage IIIc1 and 2 (5.6%) patients as stage IVa (Table 19, Figure 13).

Table 19: MRI FIGO Stage

FIGO Stage	No. of cases	Percentage
Ia	19	52.8%
Ib	10	27.8%
IIIc1	5	13.9%
IVa	2	5.6%
Total	36	100.0%

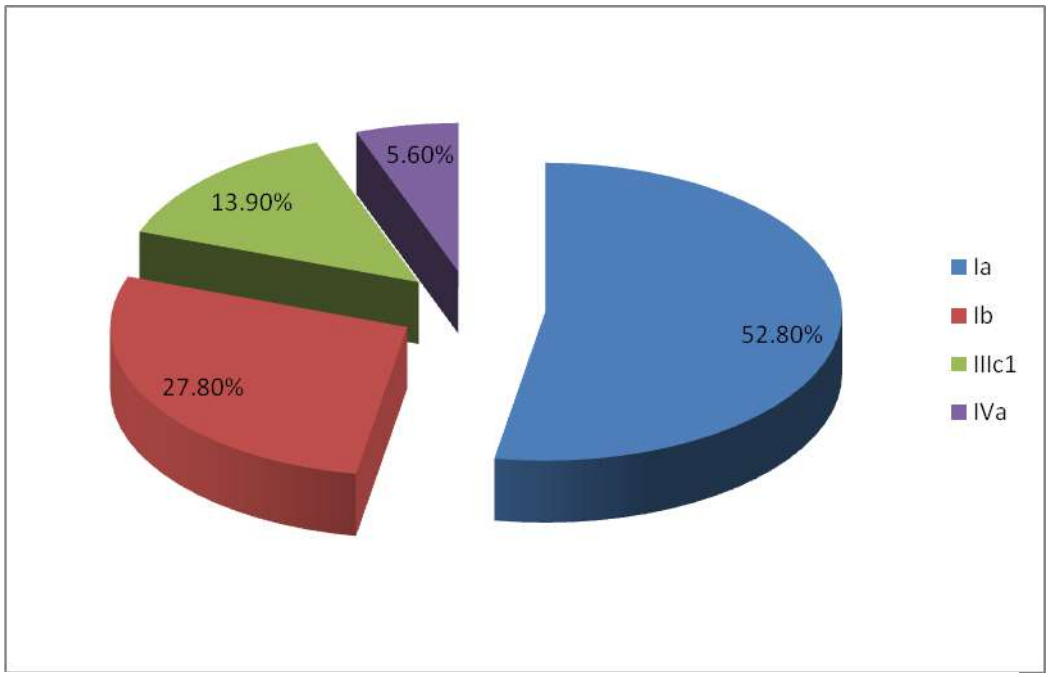


Figure 13: MRI FIGO Stage

h) ADC values of the endometrial tumor, myometrium at maximum depth of invasion and normal myometrium

The ADC values of the intracavitary endometrial tumor range between 0.42 - 0.98 x 10^{-3} mm^2/sec with mean ADC of 0.74 ± 0.12 x 10^{-3} mm^2/sec. The ADC values of the myometrium at maximum depth of invasion range between 0.56 - 0.94 x 10^{-3} mm^2/sec with mean ADC of 0.76 ± 0.09 x 10^{-3} mm^2/sec. The ADC values of the normal myometrium range between 1.13 - 1.64 x 10^{-3} mm^2/sec with mean ADC of 1.32 ± 0.11 x 10^{-3} mm^2/sec (Table 20, Figure 14).

Table 20: Range of ADC values of endometrial tumor

	ADC value (x 10^{-3} mm^2/sec)			
	Minimum	Maximum	Mean	Standard deviation
Intracavitary endometrial tumor	0.42	0.98	0.74	0.12
Myometrium at maximum depth of invasion	0.56	0.94	0.76	0.09
Normal myometrium	1.13	1.64	1.32	0.11

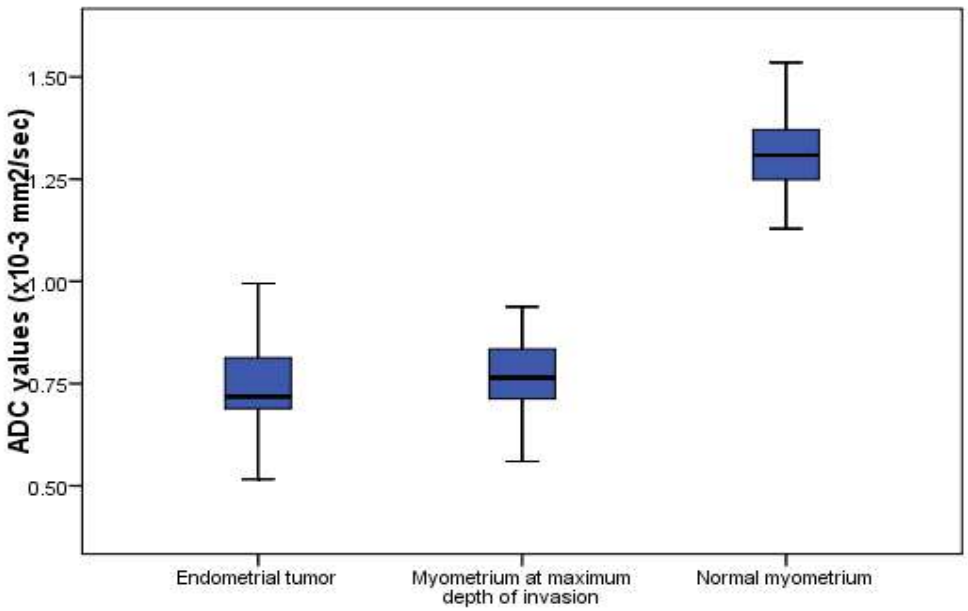


Figure 14: Box and Whisker plot showing ADC values of endometrial tumor

On comparing ADC values of intracavitary endometrial tumor and the myometrium at maximum depth of invasion, p-value was 0.153. p-values for intracavitary endometrial tumor vs normal myometrium and myometrium at maximum depth of invasion vs normal myometrium were 0.00 and 0.00 respectively (Table 21).

Table 21: Comparison of ADC values of endometrial tumor, at maximum depth of myometrial invasion and normal myometrium

Comparison sets	**p-value**
Intracavitary endometrial tumor vs Myometrium at maximum depth of invasion	0.153
Intracavitary endometrial tumor vs Normal myometrium	0.000
Myometrium at maximum depth of invasion vs Normal myometrium	0.000

5. POST-SURGICAL HISTOPATHOLOGICAL FOLLOW UP AND CORRELATION WITH MRI FINDINGS

a) Post-operative Follow-up

Out of total 36 proven cases of endometrial carcinoma evaluated on MRI, surgery was done in 30 (83.3%) patients and a definitive diagnosis was reached in these cases with regards to myometrial invasion, loco-regional spread and lymph node metastasis based on histopathology.

Surgery was deferred in 6 (16.7%) patients, either due to associated comorbidities, inoperable stage, or refusal by the patient (Table 22).

Table 22: Post-operative Follow-up

Surgical follow-up	No. of cases	Percentage
Yes	30	83.3%
No	6	16.7%
Total	36	100.0%

b) Depth of myometrial invasion on histopathology

Out of 30 patients with post-operative histopathology, 20 (66.7%) patients had less than 50% myometrial invasion and 10 (33.3%) patients had more than 50% myometrial invasion (Table 23).

Table 23: Depth of myometrial invasion on histopathology

Percentage of myometrial infiltration	No. of cases	Percentage
< 50%	20	66.7%
>50%	10	33.3%
Total	30	100.0%

c) Correlation of depth of myometrial invasion on T2 weighted MR images with histopathology

Out of 18 patients with <50% myometrial invasion on T2WI, 15 (83.3%) patients had <50% myometrial invasion on histopathology also and rest 3 (16.7%) patients had >50% myometrial invasion on histopathology.

Out of 12 patients with >50% myometrial invasion on T2WI, 7 (58.3%) patients had >50% myometrial invasion on histopathology also and rest 5 (41.7%) patients had <50% myometrial invasion on histopathology (Table 24, Figure 15).

Table 24: Correlation of depth of myometrial invasion on T2WI with histopathology

Percentage of myometrial invasion		**Histopathology**	
		< 50%	> 50%
T2 weighted MRI	< 50% (n=18)	15	3
	> 50% (n=12)	5	7
Total		20	10

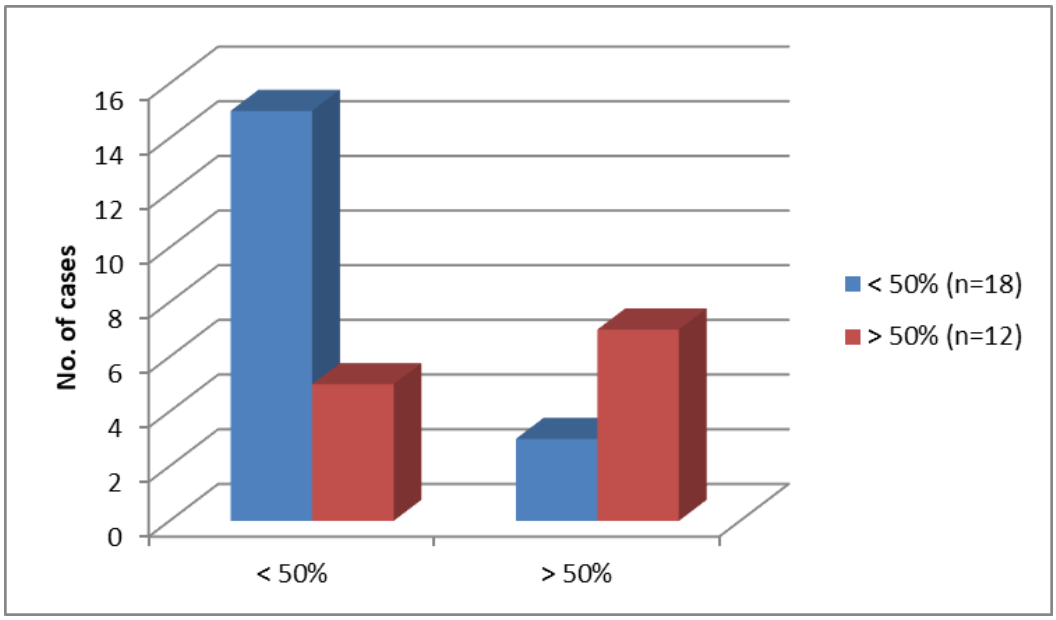


Figure 15: Correlation of depth of myometrial invasion on T2WI with histopathology

In the evaluation of deep myometrial invasion (>50%) on T2WI, the sensitivity, specificity, positive likelihood ratio, negative likelihood ratio, positive predictive value, negative predictive value and accuracy (calculated with 95% confidence intervals) were 70.00%, 75.00%, 2.8, 0.4, 58.33%, 83.33% and 73.33% respectively (Table 25).

Table 25: Statistical values for T2-W MRI in evaluation of deep myometrial invasion (calculated with 95% confidence interval)

Statistic	Value	95% CI
Sensitivity	70.00%	34.75% to 93.33%
Specificity	75.00%	50.90% to 91.34%
Positive Likelihood Ratio	2.8	1.18 to 6.62
Negative Likelihood Ratio	0.4	0.15 to 1.07
Positive Predictive Value	58.33%	37.19% to 76.80%
Negative Predictive Value	83.33%	65.24% to 93.02%
Accuracy	73.33%	54.11% to 87.72%

d) Correlation of depth of myometrial invasion on combined DWI + T2WI with histopathology

Out of 20 patients with <50% myometrial invasion on DWI + T2WI, 19 (95.0%) patients had <50% myometrial invasion on histopathology also and rest 1 (5.0%) patient had >50% myometrial invasion on histopathology.

Out of 10 patients with >50% myometrial invasion on DWI + T2WI, 9 (90.0%) patients had >50% myometrial invasion on histopathology also and rest 1 (10.0%) patient had <50% myometrial invasion on histopathology (Table 26, Figure 16).

Table 26: Correlation of depth of myometrial invasion on DWI + T2WI with histopathology

Percentage of myometrial invasion		**Histopathology**	
		< 50%	> 50%
DWI + T2WI	< 50% (n=20)	19	1
	> 50% (n=10)	1	9
Total		20	10

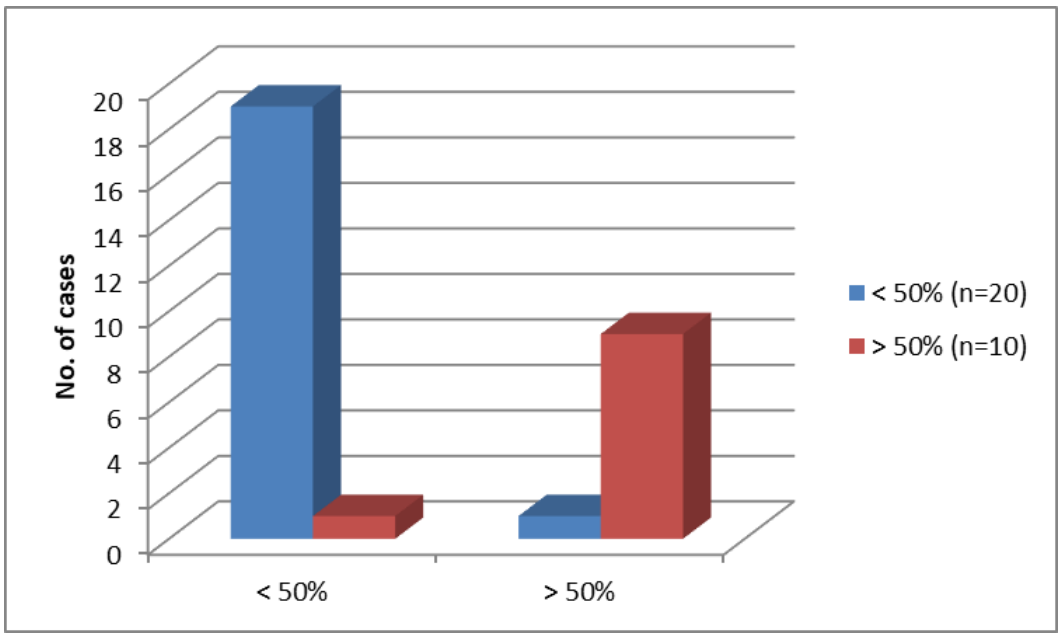


Figure 16: Correlation of depth of myometrial invasion on DWI + T2WI with histopathology

In the evaluation of deep myometrial invasion (>50%) on combined DWI + T2WI, the sensitivity, specificity, positive likelihood ratio, negative likelihood ratio, positive predictive value, negative predictive value and accuracy (calculated with 95% confidence intervals) were 90.00%, 95.00%, 18, 0.11, 90.00%, 95.00% and 93.33% respectively (Table 27).

Table 27: Statistical values for DWI + T2WI in evaluation of deep myometrial invasion (calculated with 95% confidence interval)

Statistic	Value	95% CI
Sensitivity	90.00%	55.50% to 99.75%
Specificity	95.00%	75.13% to 99.87%
Positive Likelihood Ratio	18	2.63 to 122.96
Negative Likelihood Ratio	0.11	0.02 to 0.68
Positive Predictive Value	90.00%	56.85% to 98.40%
Negative Predictive Value	95.00%	74.69% to 99.19%
Accuracy	93.33%	77.93% to 99.18%

e) Correlation of depth of myometrial invasion on combined DCE-MRI + T2WI with histopathology

Out of 19 patients with <50% myometrial invasion on DCE-MRI + T2WI, 18 (94.7%) patients had <50% myometrial invasion on histopathology also and rest 1 (5.3%) patient had >50% myometrial invasion on histopathology.

Out of 11 patients with >50% myometrial invasion on DCE-MRI + T2WI, 9 (81.8%) patients had >50% myometrial invasion on histopathology also and rest 2 (18.2%) patients had <50% myometrial invasion on histopathology (Table 28, Figure 17).

Table 28: Correlation of depth of myometrial invasion on DCE-MRI + T2WI with histopathology

Percentage of myometrial invasion		**Histopathology**	
		< 50%	> 50%
DCE-MRI + T2WI	< 50% (n=19)	18	1
	> 50% (n=11)	2	9
Total		20	10

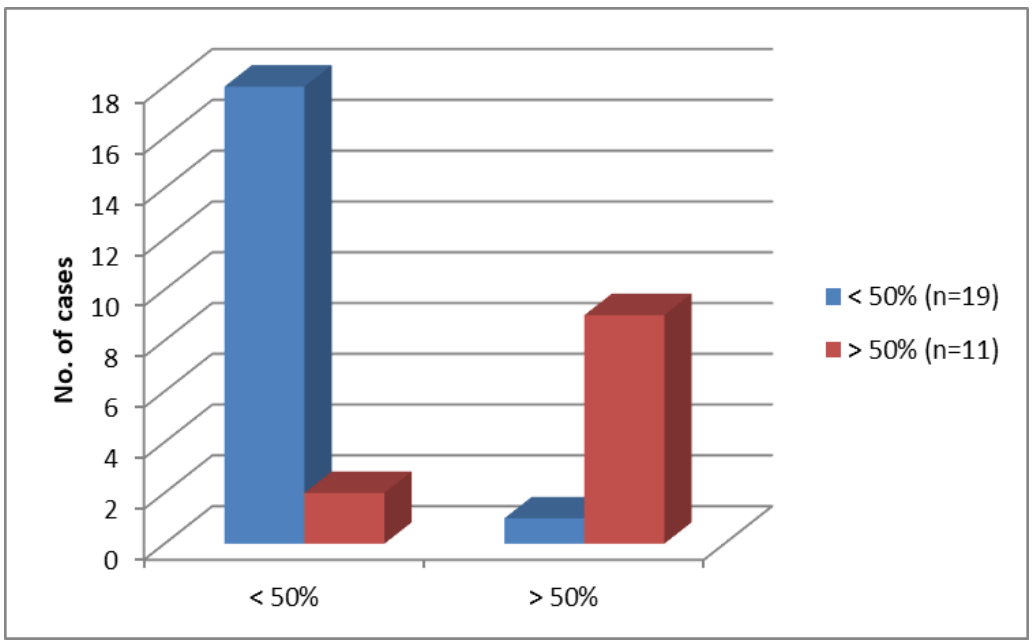


Figure 17: Correlation of depth of myometrial invasion on DCE-MRI + T2WI with histopathology

In the evaluation of deep myometrial invasion (>50%) on combined DCE-MRI + T2WI, the sensitivity, specificity, positive likelihood ratio, negative likelihood ratio, positive predictive value, negative predictive value and accuracy (calculated with 95% confidence intervals) were 90.00%, 90.00%, 9, 0.11, 81.82%, 94.74% and 90.00% respectively (Table 29).

Table 29: Statistical values for DCE-MRI + T2WI in evaluation of deep myometrial invasion (calculated with 95% confidence interval)

Statistic	Value	95% CI
Sensitivity	90.00%	55.50% to 99.75%
Specificity	90.00%	68.30% to 98.77%
Positive Likelihood Ratio	9	2.38 to 34.06
Negative Likelihood Ratio	0.11	0.02 to 0.72
Positive Predictive Value	81.82%	54.32% to 94.45%
Negative Predictive Value	94.74%	73.60% to 99.15%
Accuracy	90.00%	73.47% to 97.89%

f) Correlation of depth of myometrial invasion on combined T2WI + DWI + DCE-MRI with histopathology

Out of 20 patients with <50% myometrial invasion on T2WI + DWI + DCE-MRI, 19 (95.0%) patients had <50% myometrial invasion on histopathology also and rest 1 (5.0%) patient had >50% myometrial invasion on histopathology.

Out of 10 patients with >50% myometrial invasion on T2WI + DWI + DCE-MRI, 9 (90.0%) patients had >50% myometrial invasion on histopathology also and rest 1 (10.0%) patient had <50% myometrial invasion on histopathology (Table 30, Figure 18).

Table 30: Correlation of depth of myometrial invasion on T2WI + DWI + DCE-MRI with histopathology

Percentage of myometrial invasion		Histopathology	
		< 50%	> 50%
T2WI + DWI + DCE-MRI	< 50% (n=20)	19	1
	> 50% (n=10)	1	9
Total		20	10

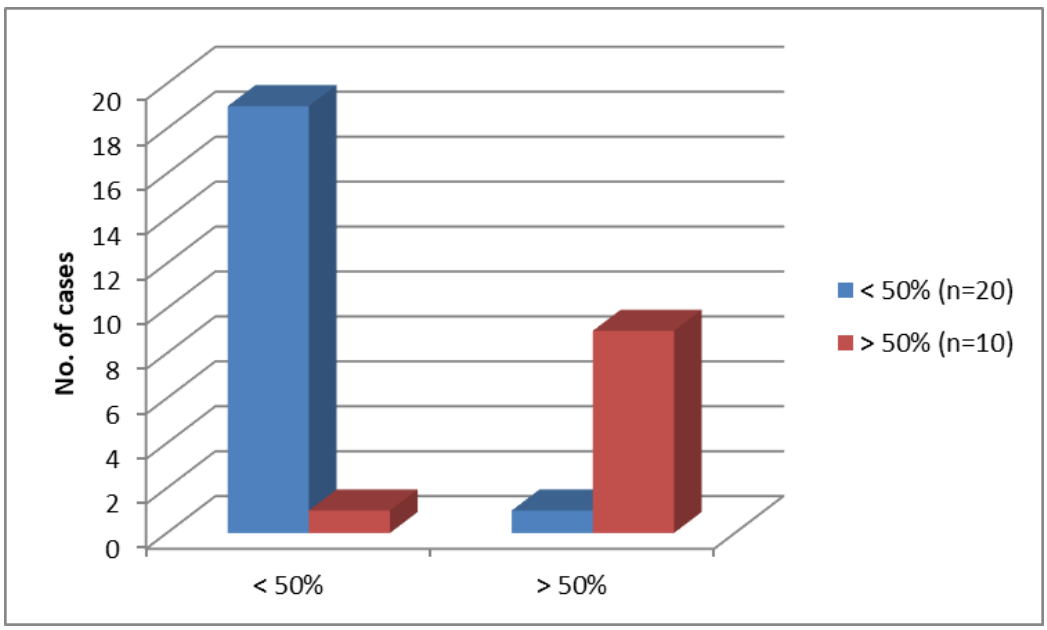


Figure 18: Correlation of depth of myometrial invasion on T2WI + DWI + DCE-MRI with histopathology

In the evaluation of deep myometrial invasion (>50%) on combined T2WI + DWI + DCE-MRI, the sensitivity, specificity, positive likelihood ratio, negative likelihood ratio, positive predictive value, negative predictive value and accuracy (calculated with 95% confidence intervals) were 90.00%, 95.00%, 18, 0.11, 90.00%, 95.00% and 93.33% respectively (Table 31).

Table 31: Statistical values for T2WI + DWI + DCE-MRI in evaluation of deep myometrial invasion (calculated with 95% confidence interval)

Statistic	Value	95% CI
Sensitivity	90.00%	55.50% to 99.75%
Specificity	95.00%	75.13% to 99.87%
Positive Likelihood Ratio	18	2.63 to 122.96
Negative Likelihood Ratio	0.11	0.02 to 0.68
Positive Predictive Value	90.00%	56.85% to 98.40%
Negative Predictive Value	95.00%	74.69% to 99.19%
Accuracy	93.33%	77.93% to 99.18%

g) Comparison of T2WI, DWI + T2WI and DCE-MRI + T2WI for evaluation of depth of myometrial invasion

On comparing each set of sequences for determining the depth of myometrial invasion, the p-value for T2WI vs DWI+T2WI was 0.017, for T2WI vs DCE-MRI+T2WI was 0.033 and for DWI + T2WI vs DCE-MRI+T2WI was 0.050 (Table 32).

Table 32: Comparison between MRI sequence sets for determining the depth of myometrial invasion

MRI sequence set pair	p-value*
T2WI versus DWI + T2WI	0.017
T2WI versus DCE-MRI + T2WI	0.033
DWI + T2WI versus DCE-MRI + T2WI	0.050

*Adjusted with the Benjamini - Hochberg procedure for controlling the false discovery rate in multiple comparisons.

h) Correlation of local and regional tumor spread on MRI with post-operative histopathology

All 30 patients who got operated did not show any evidence of cervical stromal invasion in the final histopathology report which correlated with the MRI findings.

Post-surgical follow-up was not available for the rest 6 patients (2 without cervical stromal invasion and 4 patients with cervical stromal invasion on MRI).

1 out of 30 (3.3%) patients showed adnexal invasion on histopathology which correlated with the MRI findings.

None of the patients had parametrial invasion on histopathology in concordance with the MRI report.

i) Correlation of lymph nodal metastasis on MRI with histopathology

Out of 30 patients who got operated, 2 (6.7%) patients had metastatic involvement of lymph nodes on MRI which correlated with histopathology (true positives), while 1 (3.3%) patient with metastatic lymph nodes on MRI had granulomatous inflammation of the lymph nodes on histopathology (false positive).

1 patient (3.3%) considered to have reactive enlargement of lymph nodes on MRI had metastatic involvement on histopathology (false negative).

26 (86.7%) patients with reactive/normal lymph nodes on MRI showed concordance with the final histopathology report (true negatives) (Table 33).

Table 33: Correlation of lymph nodal metastasis on MRI with histopathology

Lymph nodal metastasis (n=30)		**on Histopathology**			
		Yes		No	
On MRI	Yes	2	6.7%	1	3.3%
	No	1	3.3%	26	86.7%

The sensitivity, specificity, positive likelihood ratio, negative likelihood ratio, positive predictive value, negative predictive value and accuracy (calculated with 95% confidence intervals) of MRI for evaluation of lymph node metastasis were 66.67%, 96.30%, 18.0, 0.35, 66.67%, 96.30% and 93.33% respectively (Table 34).

Table 34: Statistical values for MRI in evaluation of lymph nodal metastasis (calculated with 95% confidence interval)

Statistic	Value	95% CI
Sensitivity	66.67%	9.43% to 99.16%
Specificity	96.30%	81.03% to 99.91%
Positive Likelihood Ratio	18	2.24 to 144.54
Negative Likelihood Ratio	0.35	0.07 to 1.72
Positive Predictive Value	66.67%	19.94% to 94.14%
Negative Predictive Value	96.30%	83.97% to 99.23%
Accuracy	93.33%	77.93% to 99.18%

j) Correlation of MRI FIGO Stage with final histopathological stage

On comparing the MRI FIGO stage with the final histopathological stage, overall concordance was seen in 26 (86.7%) cases.

In 4 (13.3%) patients, MRI FIGO stage did not correlate with the histopathological stage (Table 35, Figure 19).

Table 35: Correlation of endometrial carcinoma stage on MRI and histopathology

MRI & histopathological stage correlation	No. of cases	Percentage
Yes	26	86.7%
No	4	13.3%
Total	30	100.0%

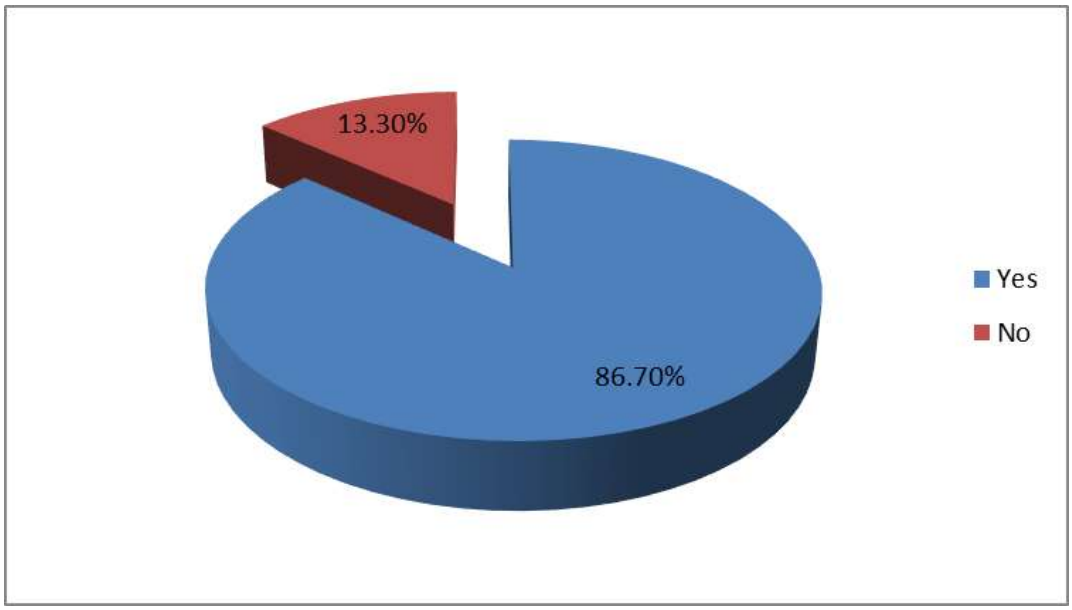


Figure 19: MRI Stage and histopathological stage correlation

2 (6.7%) patients with stage Ia and Ib on histopathology were over-staged on MRI to stage Ib and IIIc1 respectively.

2 (6.7%) patients with stage Ib and IIIc1 on histopathology were under-staged on MRI to stage Ia (Table 36).

Table 36: Correlation of MRI FIGO Stage with histopathological stage

MRI Staging	No. of Patients	Histopathological Staging		
		Concordance with MRI	Discrepancy	
			No. of Patients	Final Stage
Stage Ia	19	17	2	Ib IIIc1
Stage Ib	8	7	1	Ia
Stage IIIc1	3	2	1	Ib
Total	30 (100.0%)	26 (86.7%)	4 (13.3%)	

The overall accuracy of MRI (calculated with 95% confidence interval) in the staging of carcinoma endometrium was 86.67% (69.28% to 96.24%).

k) ADC values versus Grade of Endometrioid carcinoma

Mean ADC values for each histologic grade were 0.74 ± 0.11 x 10^{-3} mm^2/sec for Grade 1, 0.78 ± 0.15 x 10^{-3} mm^2/sec for Grade 2 and 0.71 ± 0.06 x 10^{-3} mm^2/sec for Grade 3, respectively. p-value for correlation between ADC values and tumor grade was 0.462 (Table 37, Figure 20).

Table 37: Mean ADC values for Grade of endometrial carcinoma

Grade of endometrioid carcinoma	**Number of patients**	**ADC value (x 10^{-3} mm^2/sec)**		**p-value**
		Mean	Standard deviation	
Grade 1	15	0.74	0.11	0.462
Grade 2	12	0.78	0.15	
Garde 3	2	0.71	0.06	

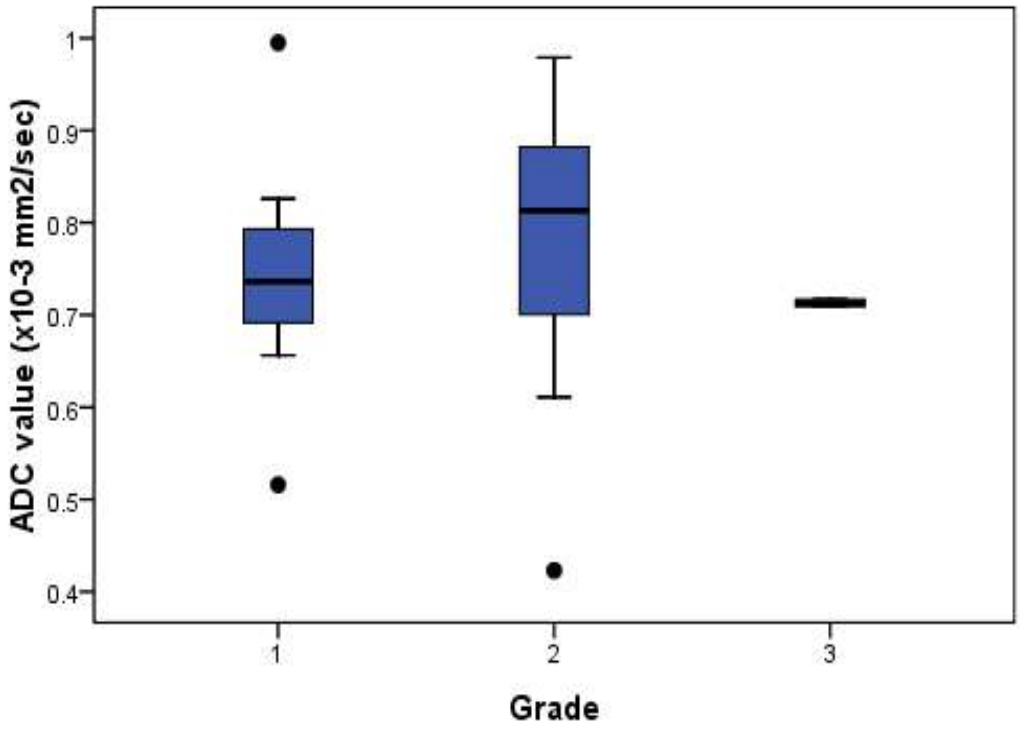


Figure 20: Box and Whisker plot showing ADC values for different Grades of endometrial carcinoma

l) ADC values versus Depth of myometrial invasion

The mean ADC values for patients with <50% myometrial invasion and for patients with >50% myometrial invasion were 0.75 ± 0.13 x 10^{-3} mm^2/sec and 0.72 ± 0.10 x 10^{-3} mm^2/sec respectively. p-value for correlation between ADC values and depth of myometrial invasion was 0.538 (Table 38, Figure 21).

Table 38: Mean ADC values for the depth of myometrial invasion

Depth of myometrial invasion	Number of patients	ADC value (x 10^{-3} mm^2/sec)		p-value
		Mean	Standard deviation	
<50%	20	0.75	0.13	0.538
>50%	10	0.72	0.10	

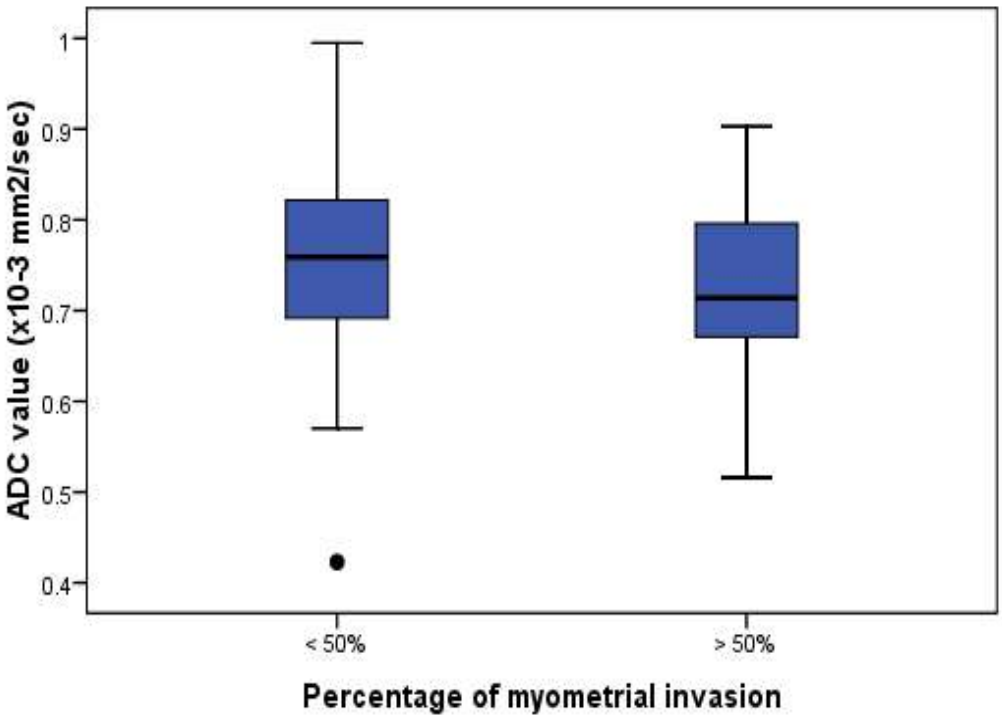


Figure 21: Box and Whisker plot showing ADC values for depth of myometrial invasion

DISCUSSION

Endometrial carcinoma is the most common malignant tumor in female pelvis and its incidence is steadily rising because of prolonged life span and escalating levels of obesity.[9,11,12] The prognosis of patients with endometrial cancer mainly depends on three factors: histologic subtype and grade, tumor stage including depth of myometrial invasion, and lymph node status.[74] Therefore, preoperative knowledge of these factors represents a critical step in planning treatment and tailoring the surgical approach. Pre-operative identification of tumor characteristics predictive of nodal metastasis, such as deep myometrial invasion and high tumor grade, helps surgeons to avoid unnecessary nodal dissection.[75] Based on staging, depth of myometrial invasion and cervical stromal involvement, the type of surgery can differ from a simple hysterectomy without lymphadenectomy or only a lymph node sampling to radical surgery with systematic lymphadenectomy.[23,76] MRI is the most accurate imaging modality for pre-treatment local staging of endometrial carcinoma.

The purpose of this study was to stage the endometrial carcinoma on MR imaging with special focus on the depth of myometrial invasion and to further assess the role of advanced MR sequences (DWI and DCE) in comparison to conventional T2 weighted MR images.

36 cases of biopsy proven endometrial carcinoma were enrolled in our study with the age range of 35-88 years and mean age of 61 years. Concordantly, in a study done by Mourad et al.[64] the age range of patients was 43-78 years with mean age of 60.5 years. Thieme et al.[68] studied 35 patients with mean age of 60 years and age range between 28-83 years. Beddy et al.[44] did retrospective analysis of 48 patients with endometrial carcinoma with mean age of 65 years (range 43-89 years).

In our study, majority of the patients (n=33, 91.7%) were post-menopausal and the most common presenting symptom was post-menopausal bleeding (88.9%). Similar to this, in a study by Zandrino et

al.[57] 87% patients were post-menopausal and the most common presenting symptom was post-menopausal bleeding.

In the present study, most common histopathological subtype was endometrioid carcinoma (n=29, 80.6%), out of which 51.7% were G1, 41.4% were G2 and 6.9% were G3. Other histological subtypes included 4 cases of carcinosarcoma, 2 cases of adenocarcinoma,NOS and 1 case of papillary adenocarcinoma. This was in concordance to study done by Hori et al.[62] in which most of the cases (81.6%) had endometrioid histology, out of which 58.6% were G1, 27.6% were G2 and 13.8% were G3. In a study done by Zamani et al.[60], 90.8% cases were of endometrioid variety with well-differentiated G1 tumors in 53.7% cases. The slight difference may be due to different sample sizes.

Most of the patients in our study were overweight (50%) or obese (33.3%), which is a known risk factor for endometrial carcinoma.

The most common co-morbidity associated with carcinoma endometrium was hypertension, followed by diabetes mellitus.

On ultrasonography, all the patients had thickened endometrium.

Comparison of T2WI, Diffusion weighted images and Dynamic contrast enhanced MR images for evaluation of Depth of Myometrial invasion

In our study, 36 biopsy proven cases of carcinoma endometrium were evaluated on MR for pre-operative staging. 30 patients were operated and a definitive diagnosis was reached in these patients with regards to myometrial invasion, loco-regional spread and lymph node metastasis. Post-operative histopathology was used as a gold standard for comparison with imaging.

Surgery was deferred in 6 patients either due to high peri-operative risk, inoperable stage, or refusal by the patient.

According to the final histopathological examination, 20/30 (66.7%) patients had superficial myometrial invasion and 10/30 (33.3%) patients had deep myometrial invasion.

On T2WI, depth of myometrial invasion was correctly identified in 22 (73.3%) patients with over-estimation in 5 (16.7%) and underestimation in 3 (10%) patients. Combined DWI + T2WI correctly identified depth of myometrial invasion in 28 (93.3%) patients with over- and under-estimation in 1 (3.3%) patient each. On combined DCE-MRI + T2WI, depth of myometrial invasion was correctly identified in 27 (90.0%) patients with over-estimation in 2 (6.7%) patients and underestimation in 1 (3.3%) patient. Combined T2WI + DWI + DCE-MRI correctly identified depth of myometrial invasion in 28 (93.3%) patients with over- and under-estimation in 1 (3.3%) patient each.

The sensitivity, specificity, accuracy of T2WI, combined DWI + T2WI and combined DCE-MRI + T2WI in differentiating deep myometrial invasion from superficial myometrial invasion were 70.0%, 75.0%, 73.3%; 90.0%, 95.0%, 93.3%; and 90.0%, 90.0%, 90.0% respectively (Table 39).

Table 39: Comparison of T2WI, DWI + T2WI, DCE-MRI + T2WI and T2WI + DWI + DCE-MRI for evaluation of depth of myometrial invasion

	Myometrial invasion on Histopathology		**Statistics**		
MRI sequence	**<50% (n=20)**	**>50% (n=10)**	**Sensitivity**	**Specificity**	**Accuracy**
T2WI	15	7	70.0%	75.0%	73.3%
DWI +T2WI	19	9	90.0%	95.0%	93.3%
DCE-MRI + T2WI	18	9	90.0%	90.0%	90.0%
T2WI + DWI + DCE-MRI	19	9	90.0%	95.0%	93.3%

In our study, the combined DWI + T2WI and DCE-MRI + T2WI both demonstrated diagnostic accuracy, sensitivity and specificity superior to that of T2WI alone in the assessment of depth of myometrial invasion, the differences being statistically significant ($p<0.05$). DWI + T2WI showed higher diagnostic accuracy and specificity than DCE-MRI + T2WI for evaluation of the depth of myometrial invasion, however, the differences were not statistically significant ($p=0.05$). Combined T2WI + DWI + DCE-MRI demonstrated the same diagnostic accuracy, sensitivity and specificity as that of DWI + T2WI and slightly better diagnostic accuracy and specificity than DCE-MRI + T2WI.

Table 40: Studies reporting the Sensitivity, Specificity and Accuracy of MRI in the evaluation of depth of myometrial invasion

First Author	Year	No. of patients	Study type	MRI sequence	Sensitivity	Specificity	Accuracy	PPV	NPV
Lin [38]	2009	48	Prospective	DWI + T2	94%	80%	90%	91%	86%
				DCE	85%	60%	77%	82%	64%
Rechichi [56]	2010	47	Prospective	T2WI	92%	76%	NA	60%	96%
				DWI	85%	71%	75%	52%	92%
				DCE	69%	62%	64%	41%	84%
Beddy [44]	2012	48	Retrospective	DWI (Reader 1)	100%	84%	90%	77%	100%
				DWI (Reader 2)	88%	84%	85%	75%	93%
				DCE (Reader 1)	88%	61%	71%	56%	90%
				DCE (Reader 2)	82%	77%	79%	67%	90%
Hori [62]	2013	71	Prospective	DWI	95%	85%	87%	69%	98%
				DCE	79%	81%	80%	60%	91%

Andreano [63]	2014	442	Meta-analysis	DWI	86%	86%	NA	NA	NA
				DCE	86%	82%	NA	NA	NA
Mourad [64]	2016	62	Prospective	DWI + T2	96%	90%	92%	NA	NA
				DCE + T2	83%	77%	79%	NA	NA
Thieme [68]	2018	35	Prospective	DWI	92%	95%	94%	92%	95%
				DCE	92%	86%	89%	80%	95%
Takeuchi [67]	2018	25	Retrospective	T2WI	NA	NA	68%	NA	NA
				DWI	NA	NA	96%	NA	NA
				DCE	NA	NA	92%	NA	NA
Gil [73]	2019	44	Retrospective	T2WI	58%	64%	61%	55%	55%
				DWI + T2	95%	96%	95%	95%	95%
				DCE + T2	84%	88%	86%	88%	88%
Present Study	2020	30	Prospective	T2WI	70%	75%	73%	58%	83%
				DWI + T2	90%	95%	93%	90%	95%
				DCE + T2	90%	90%	90%	82%	94%

Our study results showed that combined DWI + T2WI and combined DCE-MRI + T2WI both have better diagnostic accuracy (93% and 90% respectively) for evaluation of the depth of myometrial invasion than T2WI alone (73%).

DWI + T2WI compared to DCE-MRI + T2WI showed a slightly better diagnostic accuracy (93% vs 90%), a higher specificity (95% vs 90%) and the same level of sensitivity (90%) in assessing the depth of myometrial invasion in endometrial carcinoma, indicating that DWI is equivalent to or slightly better than DCE-MRI and can replace it in the pre-operative staging of endometrial carcinoma especially for patients in whom contrast agents are contraindicated.

These results are consistent with those of retrospective study conducted by Beddy et al.[44] who compared the diagnostic performance of DWI and DCE and concluded that DW-MR imaging is highly accurate in assessing the depth of myometrial invasion and might be able to replace DCE-MRI in pre-operative evaluation of endometrial cancer. The sensitivity, specificity and accuracy respectively for reader 1 / reader 2 were 100/88%, 84/84% and 90/85% for DWI and 88/82%, 61/77% and 71/79% for DCE. The slight difference might be due to the different magnetic field strengths of MR systems used for evaluation (1.5 T in the study by Beddy et al. and 3 T in our study).

Concordantly, Gil et al.[73] found in a retrospective study that DWI combined with T2WI is more accurate in assessing the depth of myometrial invasion than DCE. They reported sensitivity, specificity and accuracy of 95%, 96% and 95% respectively for DWI compared to 84%, 88% and 86% respectively for DCE.

Similar to our study, Thieme et al.[68] also reported slightly better diagnostic accuracy and specificity of DWI compared to DCE imaging.

A study by Lin et al.[38] comparing the fused T2 and DWI with that of DCE-MRI for pre-operative evaluation of myometrial invasion reported higher sensitivity, specificity and accuracy of fused T2 and DWI (94%, 80% and 90% respectively) as compared to DCE-MRI (85%, 60% and 77% respectively), which is close to our results.

In contrast to our study, Shen et al.[54] reported the diagnostic accuracy for DWI and DCE-MRI to be 62% and 71% respectively and concluded that DCE is better than DWI in the evaluation of depth of myometrial invasion, reasoning that DWI had poor resolution relative to other sequences. Our study showed better diagnostic accuracy of DWI in contrast to DCE, because we evaluated T2WI and DWI together in an attempt to resolve the inadequate anatomical resolution of DWI.

Comparison of DWI and DCE-MRI imaging for assessment of cervical stromal invasion could not be evaluated because the number of patients with cervical stromal invasion was too small (n=4) and none of them got operated.

Diagnostic pitfalls in evaluation of depth of myometrial invasion

Pitfalls in evaluating the depth of myometrial invasion are summarized in Table 41.

The two leading causes of diagnostic errors were tumor extension into the cornua and adenomyosis. On T2WI, myometrial invasion depth was over-estimated in 3 patients and under-estimated in 1 patient due to tumor extension into uterine cornua. Due to thinning of myometrium in cornual regions, myometrial thickness is difficult to measure and results in inaccurate assessment of myometrial invasion depth. Even on combined DWI + T2WI and combined DCE-MRI + T2WI, cornual involvement by tumor resulted in inaccurate assessment of depth of myometrial invasion in 2 patients each.

In three patients with coexisting adenomyosis, the tumor margins adjacent to adenomyosis were not clear on T2WI due to indistinct junctional zone and hyperintense cystic areas in myometrium. On DCE-MRI, heterogenous enhancement of adenomyosis caused inaccurate assessment of myometrial invasion depth in one patient. DW/ADC images clearly demonstrated the boundary between endometrial cancer (low signal on ADC) and adenomyotic lesions (high signal on ADC).

Myometrial invasion depth was over-estimated in one patient on T2WI due to large fibroids distorting the uterine cavity.

Table 41: False positive (over-estimation) and False negative (under-estimation) results in the evaluation of myometrial invasion depth

Findings	T2WI		DWI + T2WI		DCE-MRI + T2WI	
	FP	FN	FP	FN	FP	FN
Involvement of cornua	3	1	1	1	1	1
Adenomyosis	2	1	0	0	1	0
Uterine fibroids	1	0	0	0	0	0
Total	5	3	1	1	2	1

Role of MRI for evaluation of lymph node metastasis

In assessing the lymph node metastasis, out of 30 patients, MRI showed 2 true positives, 1 false positive, 1 false negative and 27 true negative results.

In our study, the sensitivity, specificity and accuracy of MRI for evaluation of lymph node metastasis were 67%, 96% and 93% respectively. This was in concordance to the study done by Hori et al.[55] who reported similar statistical values. Our study showed similar sensitivity to the study done by Rockall et al.[53], however, our specificity and accuracy were higher. The probable reason for better results was the evaluation of lymph node shape, margins and signal intensity in addition to size in our study. However, our results have limited value because only a small number of patients had pelvic lymph node metastases.

T2WI was more helpful than DWI in the identification of metastatic lymph nodes. DWI is excellent for identifying lymph nodes in the order of a few millimeters; however, it has no additive value in the differential diagnosis of malignant versus benign nodes.[77]

Table 42: Studies reporting the Sensitivity, Specificity and Accuracy of MRI in the evaluation of lymph node metastases

First Author	Year	No. of patients	Study type	Sensitivity	Specificity	Accuracy
Hori [55]	2009	30	Prospective	50 - 75%	88 - 92 %	83 - 90%
Rockall [53]	2007	96	Prospective	66%	73%	72%
Sala [45]	2009	50	Retrospective	80%	100%	NA
Present Study	2020	30	Prospective	67%	96%	93%

Role of MRI in overall Staging of carcinoma endometrium

MRI correctly staged 26 out of 30 patients with over-staging and under-staging in 2 patients each.

In our study, the overall accuracy of MRI in the staging of carcinoma endometrium was 86.67%.

In a study by Shrivastava et al.[66], the overall staging accuracy of MRI was 75%. The reason for better results in our study was the acquisition of DWI and DCE MR images, while in study by Shrivastava et al., only T2WI and T1 post-contrast images were acquired at 1.5 Tesla MR unit.

ADC values of the endometrial tumor versus normal and invaded myometrium

The mean ADC values of the intracavitary endometrial tumor, of myometrium at maximum depth of invasion and of normal myometrium were $0.74 \pm 0.12 \times 10^{-3}$ mm^2/sec, $0.76 \pm 0.09 \times 10^{-3}$ mm^2/sec and $1.32 \pm 0.11 \times 10^{-3}$ mm^2/sec respectively.

No statistically significant difference was found between the ADC values of intracavitary endometrial tumor and the myometrium at maximum depth of invasion ($p=0.153$). However, the mean ADC values of intracavitary endometrial tumor and the myometrium at maximum depth of invasion were significantly ($p<0.05$) lower than that of normal myometrium. Our study results were in agreement with the study done by Rechichi et al.[58] who found mean ADC values of endometrial cancer to be significantly lower than that of normal myometrium. Concordantly, Deng et al.[71] found no significant difference in the mean ADC values of endometrial tumor and the peritumoral zone at maximum depth of myometrial invasion.

Based on the differences in ADC values of normal myometrium and the invaded myometrium, mean ADC values can be used to predict the myometrial invasion of endometrial carcinoma.

Correlation of ADC values and Grade of endometrioid carcinoma

Mean ADC values for each histologic grade were 0.74 ± 0.11 x 10^{-3} mm^2/sec for Grade 1, 0.78 ± 0.15 x 10^{-3} mm^2/sec for Grade 2 and 0.71 ± 0.06 x 10^{-3} mm^2/sec for Grade 3.

In our study, no significant correlation between ADC values and tumor grade was found (p=0.462). This is in agreement with the studies done by Rechichi et al.[58], Bharwani et al.[59], Bonatti et al.[69] and Kececi et al.[65] who found no significant correlation between mean ADC values and histopathological tumor grade. Yan et al.[70] found mean ADC values helpful in differentiating low grade and high grade endometrioid adenocarcinomas, however, found no significant differences in mean ADC values and tumor grades (G1, G2, and G3).

Correlation of ADC values and Depth of myometrial invasion

The mean ADC values for patients with <50% myometrial invasion and for patients with >50% myometrial invasion were 0.75 ± 0.13 x 10^{-3} mm^2/sec and 0.72 ± 0.10 x 10^{-3} mm^2/sec respectively.

In our study, no significant correlation (p=0.538) was observed between mean ADC values and degree of myometrial invasion which is similar to Rechichi et al.[58] and Nakamura et al.[61]

Limitations of Study

First, this study was a single center study with a relatively small sample size (n=36).

Second, only one imaging plane (axial oblique) was used for DWI which might affect the staging accuracy of DWI.

Because only four patients had cervical stromal invasion, we cannot comment on comparative staging accuracy for more advanced stages of the disease.

Also, in terms of pelvic lymph node metastases, our results have limited value because only three patients had pelvic lymph node metastases.

SUMMARY AND CONCLUSION

1. The present study was conducted at the Department of Radio-diagnosis, Dayanand Medical College and Hospital, Ludhiana.
2. Thirty-six patients with biopsy-proven endometrial carcinoma were included in the study.
3. Magnetic resonance imaging was performed in all patients on SIEMENS MAGNETOM SKYRA 48 Channel 3 Tesla MRI using T1- and T2-weighted imaging, diffusion weighted imaging and dynamic contrast enhanced imaging.
4. The age range of patients was 35 - 88 years with maximum number of patients in post-menopausal age group.
5. The most common presenting symptom was post-menopausal bleeding seen in 88.9% patients.
6. Most common histopathological subtype was endometrioid adenocarcinoma (80.6%), of which 15/29 cases were G1, 12/29 were G2 and 2/29 were G3.
7. Surgery (total abdominal hysterectomy and bilateral salpingo-oophorectomy with pelvic lymph nodal dissection / sampling) was done in 30 patients and post-operative histopathology was used as gold standard.
8. According to the final histopathological examination, 20/30 (66.7%) patients had superficial myometrial invasion and 10/30 (33.3%) patients had deep myometrial invasion.
9. For assessing the depth of myometrial invasion, sensitivity, specificity and accuracy respectively, were as follows: T2WI - 70%, 75% and 73%; combined DWI + T2WI - 90%, 95% and 93%; combined DCE-MRI + T2WI - 90%, 90% and 90%.
10. For the assessment of depth of myometrial invasion, combined DWI + T2WI and DCE-MRI + T2WI both demonstrated diagnostic accuracy, sensitivity and specificity superior to that of T2WI alone, the differences being statistically significant ($p<0.05$). DWI + T2WI showed higher diagnostic accuracy and specificity than DCE-MRI +

T2WI, however, the differences were not statistically significant (p=0.05).

11. Most common causes of diagnostic error in the evaluation of depth of myometrial invasion were tumor extension into the cornua and adenomyosis.
12. The sensitivity, specificity and accuracy of MRI for evaluation of lymph node metastasis were 67%, 96% and 93% respectively.
13. The overall accuracy of MRI in the staging of carcinoma endometrium was 86.7%.
14. No statistically significant difference (p=0.153) was found between the ADC values of intracavitary endometrial tumour (0.74 ± 0.12 x 10^{-3} mm^2/sec) and the myometrium at maximum depth of invasion (0.76 ± 0.09 x 10^{-3} mm^2/sec). However, the mean ADC values of intracavitary endometrial tumor and the myometrium at maximum depth of invasion were significantly (p<0.05) lower than that of normal myometrium (1.32 ± 0.11 x 10^{-3} mm^2/sec).
15. Mean ADC values for each histologic grade were 0.74 ± 0.11 x 10^{-3} mm^2/sec for Grade 1, 0.78 ± 0.15 x 10^{-3} mm^2/sec for Grade 2 and 0.71 ± 0.06 x 10^{-3} mm^2/sec for Grade 3, showing no significant correlation between ADC values and tumor grade (p=0.462).
16. The mean ADC values for patients with <50% myometrial invasion and with >50% myometrial invasion were 0.75 ± 0.13 x 10^{-3} mm^2/sec and 0.72 ± 0.10 x 10^{-3} mm^2/sec respectively, showing no significant correlation (p=0.538) between mean ADC values and degree of myometrial invasion.

CONCLUSION

1. Magnetic resonance imaging is an accurate imaging technique for the preoperative assessment of local staging of endometrial cancer and for evaluating the depth of myometrial invasion.
2. Diffusion weighted MR imaging is equivalent to or slightly better than dynamic contrast enhanced MRI and can replace it in the pre-operative staging of endometrial carcinoma, offering the potential advantages of reduced scanning time and obviation of

intravenous administration of gadolinium-based contrast agents (especially in patients with renal dysfunction or allergy to gadolinium based contrast).

3. MRI has a low sensitivity for the identification of metastatic lymph nodes.
4. Differences in ADC values of normal and invaded myometrium help in the prediction of myometrial invasion of endometrial cancer.
5. ADC values are not useful for predicting histologic tumor grade and the depth of myometrial invasion.
6. The information provided by MRI can define prognosis and help planning the surgical approach.

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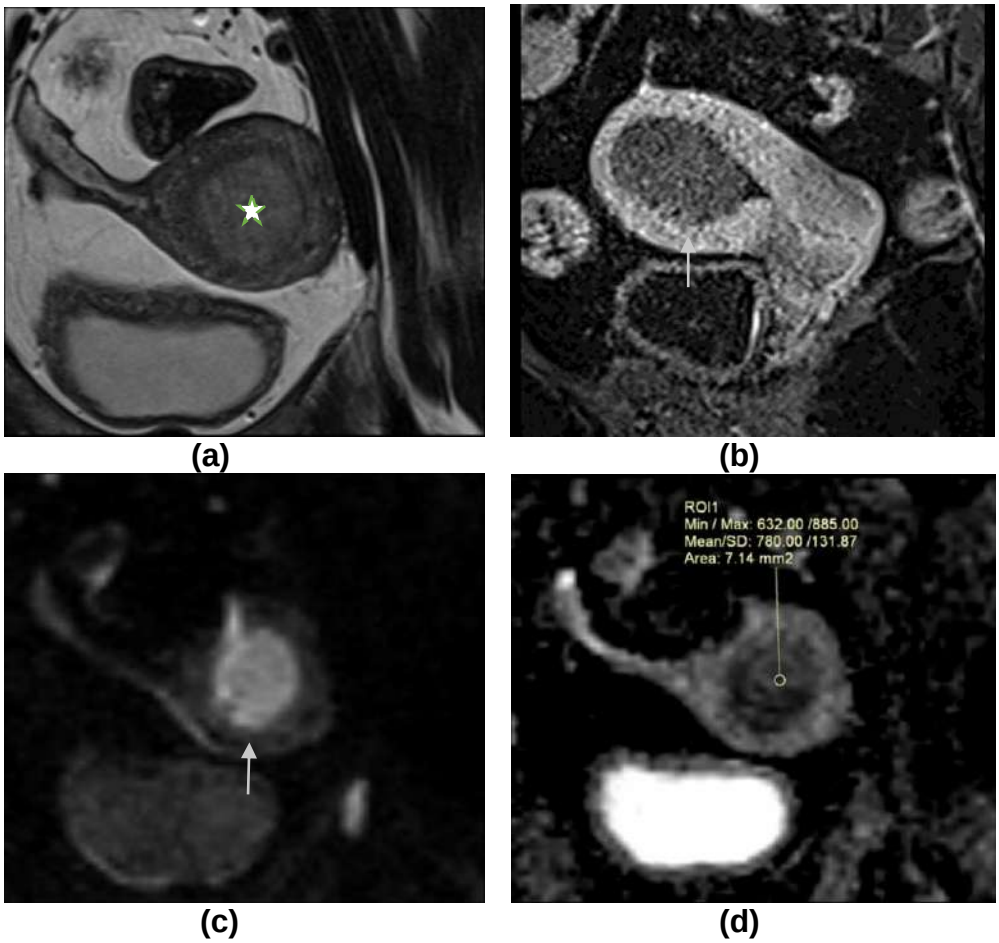
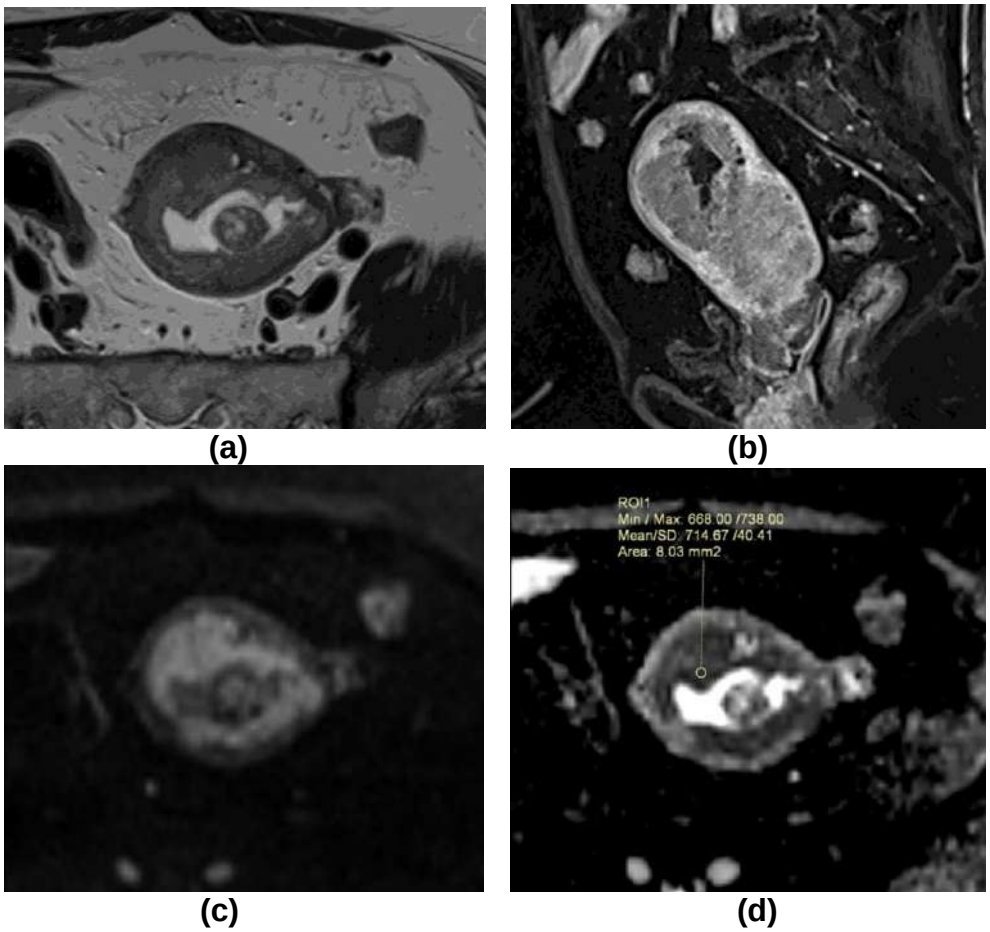
Stage Ia (<50% myometrial invasion) endometrial cancer (grade 1) in a 64-year-old female.



(a) **(b)** **(c)** **(d)**

(a) Axial oblique T2-WI shows intermediate signal intensity tumor (☆) distending the endometrial cavity. **(b)** Sagittal DCE-MRI at 2 minutes shows hypoenhancing tumor relative to the hyperenhancing myometrium with interruption of the subendometrial zone (arrow). **(c)** Axial oblique high b-value (b=1400/mm^2) DWI and **(d)** ADC images demonstrate restricted diffusion in endometrial tumor with invasion of superficial myometrium (arrow) and mean ADC value of 0.78 x 10^{-3} mm^2/sec.

Stage Ib (>50% myometrial invasion) endometrial cancer (grade 3) in a 61-year-old female.

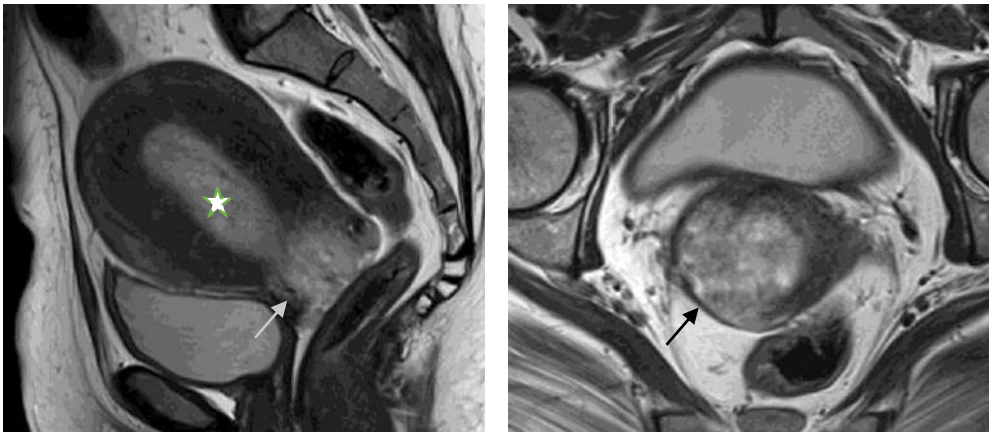


(a) **(b)**

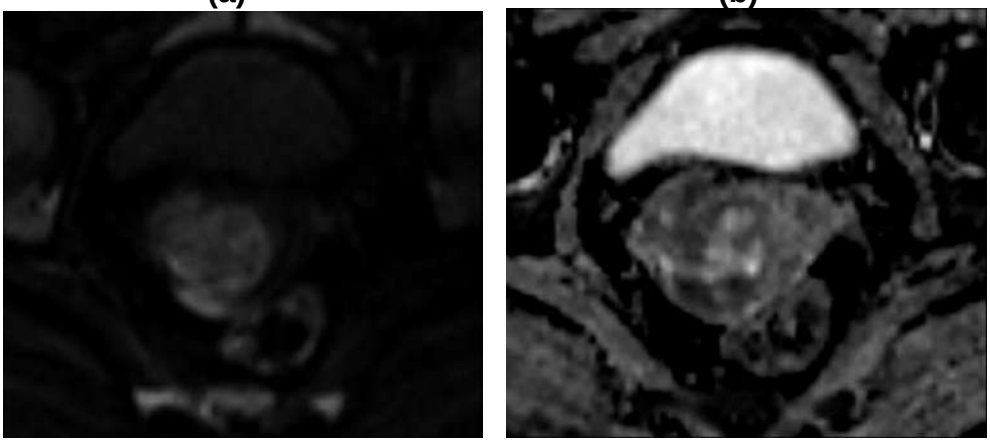
(c) **(d)**

(a) Axial oblique T2-WI demonstrates intermediate signal intensity tumor with invasion of myometrium. **(b)** Sagittal DCE-MRI shows hypoenhancing tumor with invasion of deep myometrium. **(c)** Axial oblique DWI and **(d)** ADC images show endometrial tumor with invasion of deep myometrium with mean ADC value of 0.71 x 10^{-3} mm^2/sec.

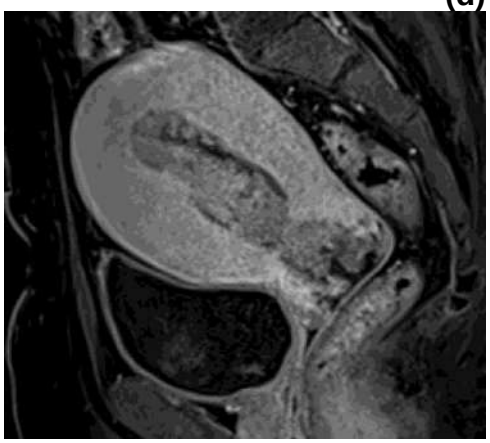
Stage II (cervical invasion) endometrial cancer in a 45-year-old female.



(a) **(b)**



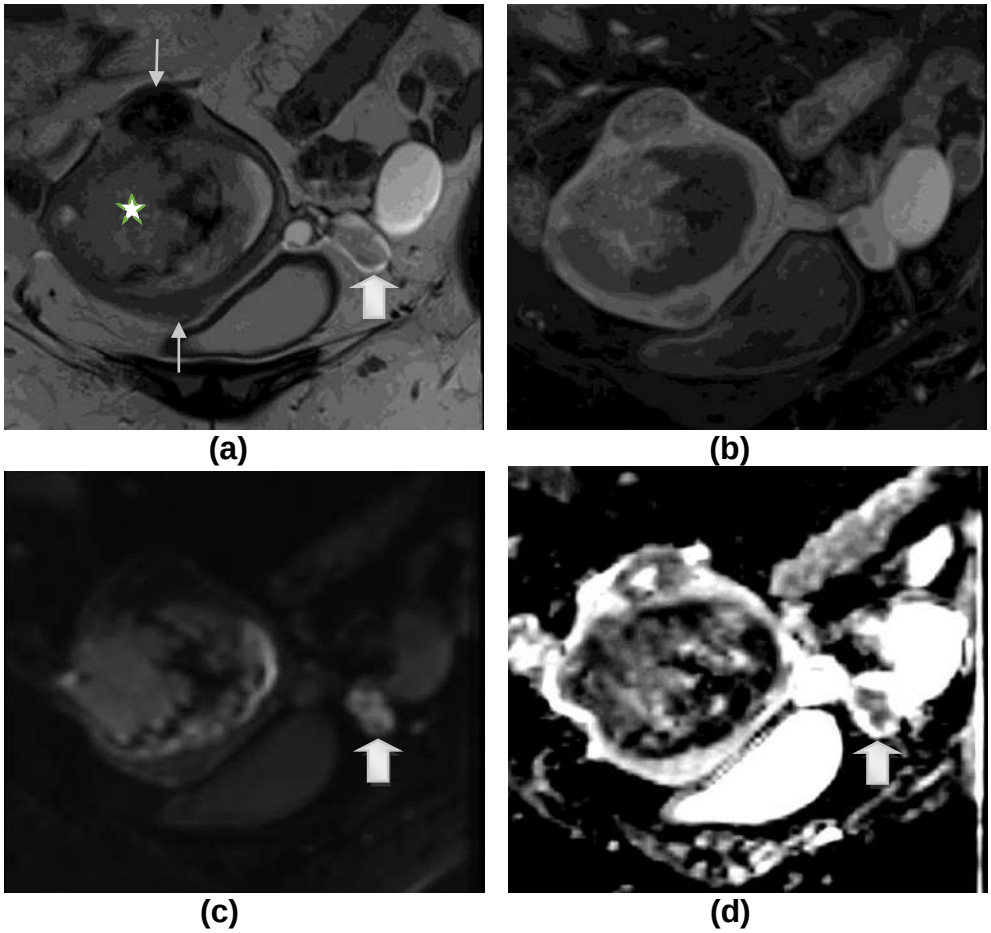
(c) **(d)**



(e)

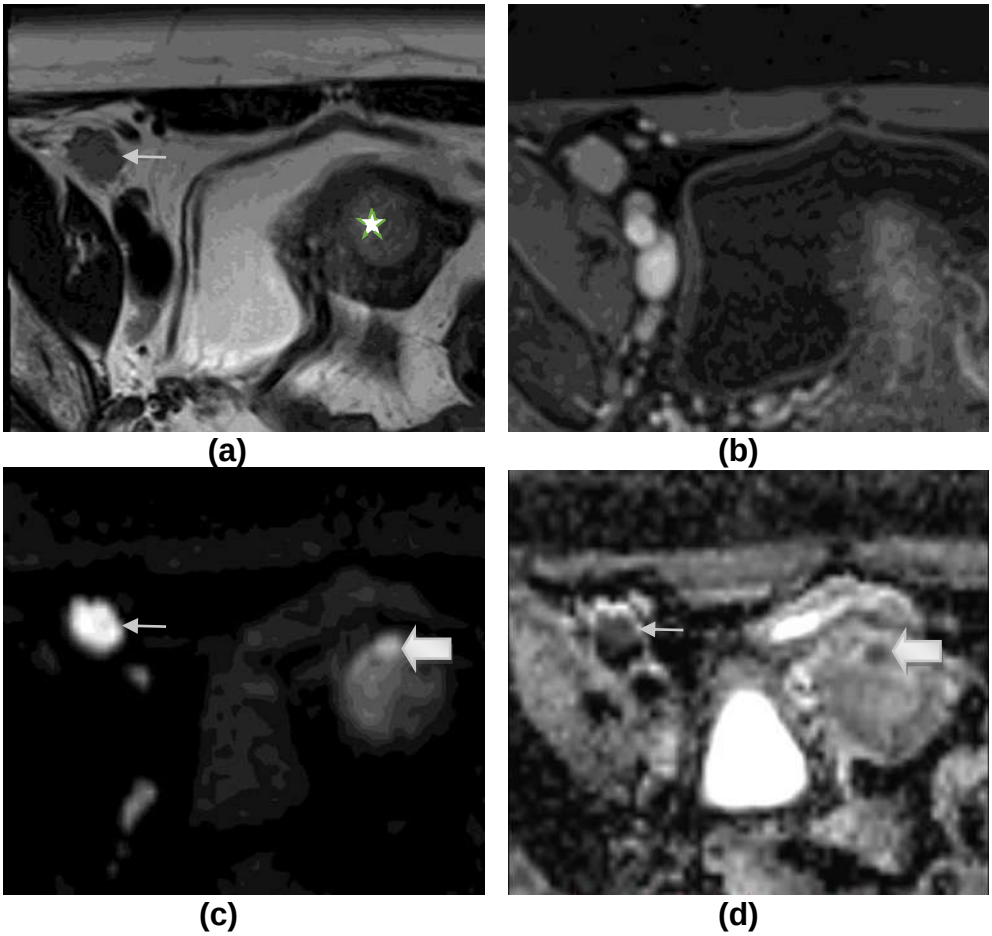
(a) Sagittal and **(b)** Axial oblique T2-WI show intermediate signal intensity tumor distending the endometrial cavity (☆) with cervical stromal invasion (arrows). **(c)** Axial oblique DWI and **(d)** ADC images demonstate restricted diffusion in tumor. **(e)** Sagittal DCE image at 3 minutes shows disruption of the normal enhancement of cervical stroma by hypoenhancing tumor.

Stage IIIa (adnexal invasion) endometrial cancer in a 64-year-old female.



(a) Axial oblique T2-WI shows a large mixed and heterogenous signal intensity mass (☆) distending the endometrial cavity with deep myometrial invasion. Left hydrosalpinx is noted with intermediate signal intensity solid component (thick arrow) within it. Hypointense fibroids (thin arrows) are also seen. **(b)** Axial oblique T1 fat sat post-contrast image shows heterogeneously enhancing endometrial tumor and enhancing solid component in hydrosalpinx. **(c)** Axial DWI and **(d)** ADC images demonstate diffusion restriction in the endometrial tumor and solid component in left fallopian tube (thick arrows).

Stage IIIc1 (pelvic lymph node metastasis) endometrial cancer in a 63-year-old female.

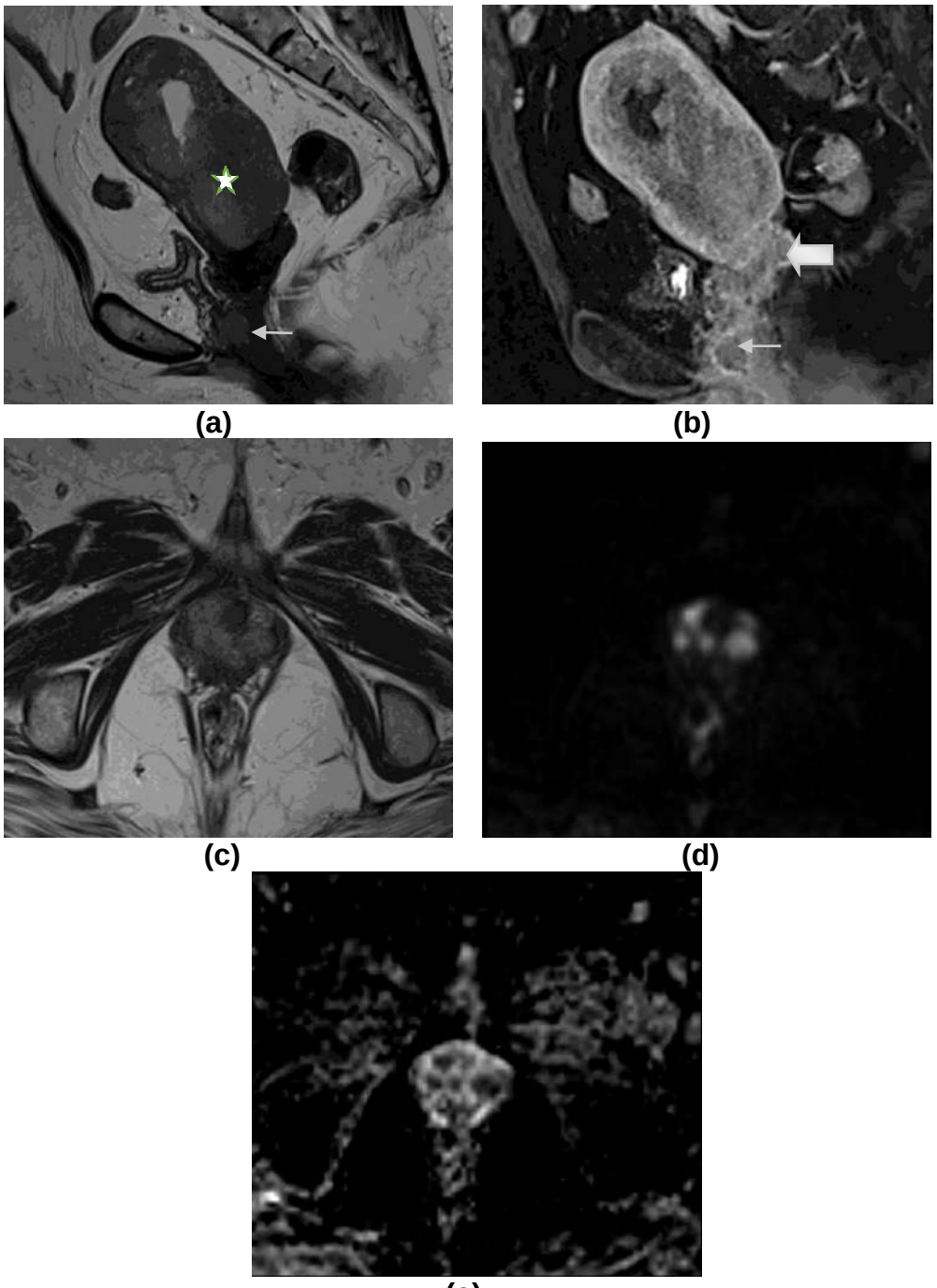


(a) **(b)**

(c) **(d)**

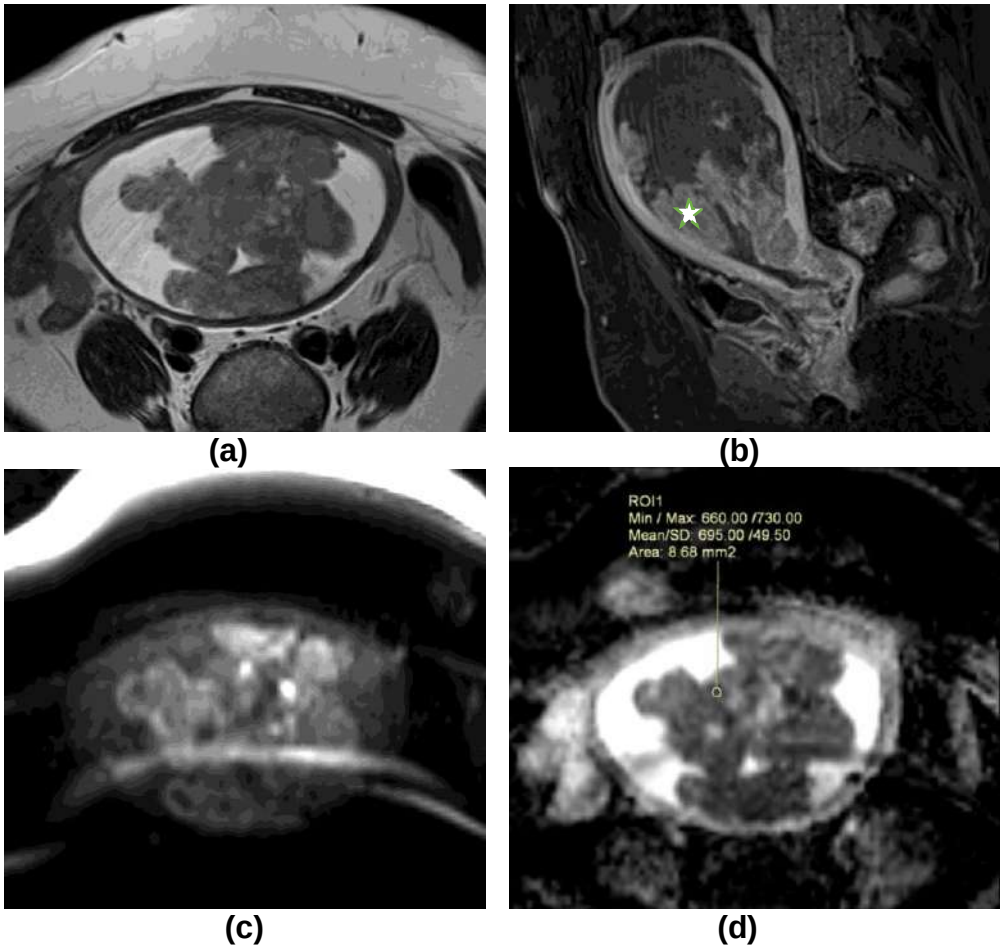
(a) Axial T2-WI shows tumor in endometrial cavity (☆) with enlarged lymph node (13mm in short axis diameter) (thin arrow) along right external iliac vessels showing intermediate signal intensity, round shape and irregular margins. **(b)** Axial T1 fat sat post-contrast image shows homogenous enhancement in the lymph node. **(c)** Axial DWI and **(d)** ADC images demonstrate diffusion restriction in the lymph node (thin arrows) and patchy nodular areas of diffusion restriction in the endometrial tumor (thick arrows).

Stage IV endometrial cancer in a 61-year-old female.



(a) Sagittal T2-WI shows intermediate signal intensity tumor in the endometrial cavity (☆) with deep myometrial invasion and deposit in urethro-vaginal septum (thin arrow). **(b)** Sagittal DCE-MRI shows heterogenous enhancement in the endometrial tumor and deposits in the urethra-vaginal septum (thin arrow) and posterior lip of cervix (thick arrow). **(c)** Axial T2-WI demonstrates intermediate signal intensity deposits in the periurethral region and urethro-vaginal septum. **(d)** Axial oblique DWI and **(e)** ADC images show diffusion restriction in the deposits.

Carcinosarcoma (Malignant mixed Mullerian tumor) in a 63-year-old female.



(a) **(b)**

(c) **(d)**

(a) Axial oblique T2-WI shows a large mixed and heterogenous signal intensity tumor distending the endometrial cavity. **(b)** Sagittal DCE-MRI at 1minute shows heterogenous enhancement of the tumor. **(c)** Axial oblique DWI and **(d)** ADC images show endometrial tumor with diffusion restriction and mean ADC value of 0.69 x 10^{-3} mm^2/sec.

KEY TO MASTER CHART

CA	Carcinoma
DVT	Deep venous thrombosis
HPE	Histopathological examination
ITP	Idiopathic thrombocytopenic purpura
SAD	Short axis diameter

Case No.	Name	MRD	Year	Age (years)	Menopausal Status	Clinical complaints	BMI	Co-Morbidities			Endometrial Thickness on Ultrasound	Pre imaging Biopsy	Size of Lesion (cm)	Signal on T2	DWI signal	ADC	ADC value			DCE	Percentage of Myometrial Invasion				Cervical Invasion	Serosal Invasion
								Diabetes	Hypertension	Others							Endometrial tumor	Myometrium at maximum depth of invasion	Normal myometrium		T2 + DWI + DCE	T2-WI	DWI	DCE		
1	KB	586249	2018	35	Pre-menopausal	Abnormal vaginal bleeding	33	No	No	No	14mm	Adenocarcinoma	1.5 x 0.9	Intermediate	Bright	Dark	979	No	1350	Hypoenhancing	<50%	<50%	<50%	<50%	No	No
2	SLG	588587	2018	62	Post-menopausal	Post-menopausal bleeding	25	Yes	No	Cirrhosis	11mm	Endometrioid adenocarcinoma	2.7 x 1.5	Intermediate	Bright	Dark	782	795	1281	Hypoenhancing	<50%	<50%	<50%	<50%	No	No
3	PK	599520	2018	58	Post-menopausal	Post-menopausal bleeding	35	No	No	Migraine	17mm	Adenocarcinoma	3.1 x 1.6	Mixed and heterogeneous	Bright	Dark	745	802	1316	Hypoenhancing	>50%	>50%	>50%	>50%	No	No
4	VR	278317	2018	59	Post-menopausal	Post-menopausal bleeding	32	Yes	Yes	No	20mm	Papillary adenocarcinoma	4.9 x 2.2	Mixed and heterogeneous	Bright	Dark	736	712	1275	Hypoenhancing	<50%	>50%	<50%	<50%	No	No
5	SG	611171	2018	59	Post-menopausal	Post-menopausal bleeding	35	No	Yes	No	12mm	Endometrial intraepithelial carcinoma	4.3 x 2.0	Intermediate	Bright	Dark	796	816	1211	Hypoenhancing	>50%	<50%	>50%	>50%	No	No
6	CKA	615324	2018	57	Post-menopausal	Post-menopausal bleeding	28	No	Yes	No	10mm	Adenosquamous cell carcinoma	2.7 x 2.4	Intermediate	Bright	Dark	708	718	1227	Hypoenhancing	<50%	>50%	<50%	<50%	No	No
7	MB	633257	2018	60	Post-menopausal	Post-menopausal bleeding	30	No	Yes	Hypothyroid	19mm	Adenocarcinoma	2.3 x 1.3	Intermediate	Bright	Dark	694	715	1129	Hypoenhancing	<50%	>50%	<50%	>50%	No	No
8	HPK	544749	2018	63	Post-menopausal	Post-menopausal bleeding	25	No	No	No	37mm	Endometrioid adenocarcinoma	6.7 x 3.8	Intermediate	Bright and heterogeneous	Dark and heterogenous	671	692	1274	Heterogenous enhancement	>50%	>50%	>50%	>50%	No	Yes
9	RK	576038	2019	45	Peri-menopausal	Abnormal vaginal bleeding	28	Yes	No	Hypothyroid	28mm	Endometrioid adenocarcinoma, grade II	9x 2.7	Intermediate	Bright	Dark	952	661	1162	Hypoenhancing	>50%	>50%	>50%	>50%	Yes	No
10	KC	652644	2019	57	Post-menopausal	Post-menopausal bleeding	27	No	No	Hypothyroid	13mm	Endometrioid adenocarcinoma	2.8 x 2.4	Mixed and heterogenous	Bright	Dark	698	823	1147	Hypoenhancing	>50%	<50%	>50%	>50%	No	No
11	RR	660458	2019	58	Post-menopausal	Post-menopausal bleeding	38	Yes	Yes	No	23mm	Adenocarcinoma	4.1 x 2.1	Intermediate	Bright	Dark	809	938	1314	Hypoenhancing	>50%	>50%	>50%	>50%	No	No
12	DK	664193	2019	55	Post-menopausal	Post-menopausal bleeding	29	No	No	Rheumatoid Arthritis	25mm	Endometrioid adenocarcinoma	4.2 x 1.7	Intermediate	Bright	Dark	903	714	1350	Hypoenhancing	>50%	>50%	>50%	>50%	No	No
13	GK	681472	2019	63	Post-menopausal	Post-menopausal bleeding	31	Yes	Yes	No	76mm	Malignant mixed mullerian tumor	12.0 x 8.2	Mixed and heterogenous	Bright	Dark	712	891	1439	Heterogenous enhancement	<50%	<50%	<50%	<50%	No	No
14	AM	693050	2019	48	Pre-menopausal	Abnormal vaginal bleeding	30	No	Yes	No	21mm	Endometrioid adenocarcinoma	1.6 x 1.1	Intermediate	Bright	Dark	861	827	1351	Hypoenhancing	<50%	<50%	<50%	<50%	No	No
15	PK	695031	2019	60	Post-menopausal	Post-menopausal bleeding	35	Yes	Yes	No	8mm	Adenocarcinoma, NOS	2.4 x 0.7	Intermediate	Bright	Dark	611	625	1285	Hypoenhancing	<50%	<50%	<50%	<50%	No	No
16	HK	728808	2019	61	Post-menopausal	Post-menopausal bleeding	31	No	No	No	25mm	Adenocarcinoma	4.1 x 2.3	Intermediate	Bright	Dark	995	891	1495	Hypoenhancing	<50%	<50%	<50%	<50%	No	No
17	SLG	725650	2019	50	Post-menopausal	Incidentally detected	29	No	Yes	No	52mm	Malignant mixed mullerian tumor	10.8 x 5.5	Mixed and heterogeneous	Bright and heterogeneous	Dark and heterogenous	795	No	1637	Heterogenous enhancement	<50%	<50%	<50%	<50%	No	No
18	MO	230111	2019	57	Post-menopausal	Post-menopausal bleeding	25	No	No	CA ascending colon	19mm	Adenocarcinoma, NOS	2.8 x 1.9	Intermediate	Bright	Dark	689	No	1496	Hypoenhancing	<50%	<50%	<50%	<50%	No	No
19	SR	799955	2019	60	Post-menopausal	Post-menopausal bleeding	31	No	Yes	No	20mm	Endometrial intraepithelial carcinoma	4.2 x 1.5	Intermediate	Bright	Dark	851	762	1143	Hypoenhancing	<50%	>50%	<50%	<50%	No	No
20	BK	764043	2019	88	Post-menopausal	Post-menopausal bleeding	21	No	No	No	46mm	Papillary adenocarcinoma	9.1 x 4.8	Intermediate	Bright	Dark	684	757	1320	Heterogenous enhancement	>50%	>50%	>50%	>50%	Yes	Yes
21	MK	828457	2019	55	Post-menopausal	Post-menopausal bleeding	30	Yes	No	No	10mm	Endometrioid adenocarcinoma	3.0 x 0.9	Intermediate	Bright	Dark	826	850	1290	Hypoenhancing	<50%	<50%	<50%	<50%	No	No
22	SD	854142	2019	64	Post-menopausal	Post-menopausal bleeding	37	Yes	Yes	No	28mm	Endometrioid adenocarcinoma	4.2 x 2.9	Intermediate	Bright	Dark	785	767	1219	Hypoenhancing	>50%	>50%	>50%	>50%	No	No
23	SK	866010	2019	58	Post-menopausal	Post-menopausal bleeding	34	No	Yes	Hypothyroid	12mm	Adenocarcinoma	4.7 x 1.7	Intermediate	Bright	Dark	817	846	1293	Hypoenhancing	<50%	<50%	<50%	<50%	No	No
24	UK	866165	2019	61	Post-menopausal	Post-menopausal bleeding	30	No	Yes	No	17mm	Malignant mixed mullerian tumor	4.3 x 1.8	Intermediate	Bright	Dark	712	860	1424	Hypoenhancing	<50%	<50%	<50%	<50%	No	No
25	SG	203188	2019	69	Post-menopausal	Post-menopausal bleeding	28	Yes	Yes	No	13mm	Endometrioid adenocarcinoma, grade II	2.5 x 1.2	Intermediate	Bright	Dark	703	785	1348	Hypoenhancing	>50%	>50%	>50%	>50%	No	No
26	PPK	884052	2020	69	Post-menopausal	Post-menopausal bleeding	27	Yes	Yes	Hypothyroid	23mm	Endometrioid adenocarcinoma	3.8 x 2.2	Intermediate	Bright	Dark	423	No	1231	Hypoenhancing	<50%	<50%	<50%	<50%	No	No
27	JK	891201	2020	58	Post-menopausal	Post-menopausal bleeding	25	No	Yes	Hypothyroid, CA Breast	24mm	Endometrioid adenocarcinoma	8.5 x 3.2	Intermediate	Bright	Dark	656	568	1397	Hypoenhancing	<50%	<50%	<50%	<50%	No	No
28	KR	904457	2020	72	Post-menopausal	Post-menopausal bleeding	28	No	Yes	No	28mm	Endometrioid adenocarcinoma	4.2 x 2.7	Intermediate	Bright	Dark	719	632	1445	Hypoenhancing	>50%	>50%	>50%	>50%	No	No
29	PK	914451	2020	62	Post-menopausal	Post-menopausal bleeding	29	No	No	No	19mm	Adenocarcinoma	5.3 x 2.1	Intermediate	Bright	Dark	670	760	1240	Hypoenhancing	<50%	<50%	<50%	<50%	No	No
30	AR	928792	2020	70	Post-menopausal	Post-menopausal bleeding	27	No	Yes	DVT left lower limb	21mm	Adenocarcinoma, NOS	5.2 x 3.4	Intermediate	Bright	Dark	664	725	1258	Hypoenhancing	>50%	>50%	>50%	>50%	Yes	No
31	NI	39758	2020	64	Post-menopausal	Post-menopausal bleeding	26	No	Yes	ITP	57mm	Adenocarcinoma, NOS	9.0 x 5.8	Mixed and heterogeneous	Mixed areas of bright and dark signal	Dark and heterogenous	709	716	1535	Heterogenous enhancement	>50%	>50%	>50%	>50%	No	Yes
32	BR	928566	2020	68	Post-menopausal	Post-menopausal bleeding	26	Yes	Yes	Hypothyroid	12mm	Papillary adenocarcinoma	2.1 x 1.4	Intermediate	Bright	Dark	790	853	1355	Avid early enhancement	<50%	<50%	<50%	<50%	No	No
33	AS	932317	2020	64	Post-menopausal	Post-menopausal bleeding	27	No	Yes	Bronchial asthma	11mm	Endometrioid adenocarcinoma	3.4 x 1.9	Intermediate	Bright	Dark	516	560	1376	Hypoenhancing	>50%	>50%	>50%	>50%	No	No
34	KK	6742	2020	66	Post-menopausal	Post-menopausal bleeding	23	No	No	No	28mm	Malignant mixed mullerian tumor	4.1 x 4.2	Mixed and heterogenous	Bright and heterogeneous	Dark and heterogenous	570	632	1405	Heterogenous enhancement	<50%	<50%	<50%	<50%	No	No
35	SG	963647	2020	61	Post-menopausal	Post-menopausal bleeding	28	No	Yes	No	45mm	Endometrioid adenocarcinoma, grade III	6.1 x 4.4	Intermediate	Bright	Dark	717	788	1366	Heterogenous enhancement	>50%	>50%	>50%	>50%	Yes	Yes
36	BK	50007	2020	69	Post-menopausal	Post-menopausal bleeding	31	Yes	Yes	No	29mm	Endometrioid adenocarcinoma, grade I	3.4 x 0.9	Intermediate	Bright	Dark	826	842	1303	Hypoenhancing	>50%	>50%	>50%	>50%	No	No

Case No.	Name	MRD	Adnexal Invasion	Parametrial Invasion	Visceral Invasion	Lymph Nodes						Fibroids	Adenomyosis	Other Adnexal Findings	FIGO Stage	Surgical Follow Up	Histopathology	Grade	Percentage of myometrial infiltration	Cervical invasion	Adnexal invasion	Parametrial invasion	Lymph nodal deposits	Lymphovascular invasion	TNM Stage	MRI & HPE Correlation	
						Shape	Margins	Size (SAD)	Signal Intensity on T2	Necrosis	Metastasis															Myometrial Invasion	Overall Stage
1	KB	586249	No	No	No	Oblong	Regular	7mm	Homogenous	No	No	No	No	None	Ia	Yes	Endometrioid adenocarcinoma	Grade II	<50%	No	No	No	Reactive	No	T1a N0	Yes	Yes
2	SLG	588587	No	No	No	Oblong	Regular	7mm	Homogenous	No	No	No	Yes	None	Ia	Yes	Endometrioid adenocarcinoma	Grade I	<50%	No	No	No	Reactive	No	T1a N0	Yes	Yes
3	PK	599520	No	No	No	Oblong	Regular	8mm	Homogenous	No	No	Yes	No	None	Ib	Yes	Endometrioid adenocarcinoma	Grade II	>50%	No	No	No	Reactive	No	T1b N0	Yes	Yes
4	VR	278317	No	No	No	Oblong	Regular	7mm	Homogenous	No	No	Yes	No	None	Ia	Yes	Endometrioid adenocarcinoma	Grade I	<50%	No	No	No	Reactive	No	T1a N0	Yes	Yes
5	SG	611171	No	No	No	Oblong	Regular	8mm	Homogenous	No	No	No	No	None	Ib	Yes	Endometrioid adenocarcinoma	Grade I	>50%	No	No	No	Reactive	No	T1b N0	Yes	Yes
6	CKA	615324	No	No	No	Oblong	Regular	4mm	Homogenous	No	No	Yes	Yes	None	Ia	Yes	Endometrioid adenocarcinoma	Grade I	<50%	No	No	No	Reactive	No	T1a N0	Yes	Yes
7	MB	633257	No	No	No	Oblong	Regular	10mm	Homogenous	No	No	Yes	Yes	None	Ia	Yes	Endometrioid adenocarcinoma	Grade I	<50%	No	No	No	Yes	No	T1a N1	Yes	No, lymph nodes
8	HPK	544749	No	No	No	Round	Irregular	13mm	Intermediate	No	Yes	Yes	No	Thickening in right adnexa and left ovarian cyst	IIIc1	Yes	Endometrioid adenocarcinoma	Grade I	>50%	No	No	No	Granulomatous inflammation	No	T1b N0	Yes	No, lymph nodes
9	RK	576038	Yes	No	Yes	Round	Irregular	17mm	Intermediate	No	Yes	No	Yes	None	IVa	No, Patient expired											
10	KC	652644	No	No	No	Oblong	Regular	8mm	Homogenous	No	No	No	No	None	Ib	Yes	Endometrioid adenocarcinoma	Grade II	>50%	No	No	No	Reactive	No	T1b N0	Yes	Yes
11	RR	660458	No	No	No	Oblong	Regular	6mm	Homogenous	No	No	No	No	None	Ib	Yes	Endometrioid adenocarcinoma	Grade II	>50%	No	No	No	Reactive	No	T1b N0	Yes	Yes
12	DK	664193	No	No	No	Oblong	Regular	6mm	Homogenous	No	No	No	No	None	Ib	Yes	Endometrioid adenocarcinoma	Grade II	>50%	No	No	No	Reactive	No	T1b N0	Yes	Yes
13	GK	681472	No	No	No	Round	Irregular	18mm	Intermediate	No	Yes	No	No	None	IIIc1	Yes	Carcinosarcoma		<50%	No	No	No	Yes	No	T1a N1	Yes	Yes
14	AM	693050	No	No	No	Oblong	Regular	4mm	Homogenous	No	No	Yes	Yes	Thickening in bilateral adnexa and right ovarian cyst	Ia	Yes	Endometrioid adenocarcinoma	Grade II	<50%	No	No	No	Reactive	No	T1a N0	Yes	Yes
15	PK	695031	No	No	No	Oblong	Regular	7mm	Homogenous	No	No	No	No	None	Ia	Yes	Endometrioid adenocarcinoma	Grade II	<50%	No	No	No	Reactive	No	T1a N0	Yes	Yes
16	HK	728808	No	No	No	Oblong	Regular	6mm	Homogenous	No	No	Yes	No	None	Ia	Yes	Endometrioid adenocarcinoma	Grade I	<50%	No	No	No	Reactive	No	T1a N0	Yes	Yes
17	SLG	725650	No	No	No	Oblong	Regular	5mm	Homogenous	No	No	No	No	None	Ia	Yes	Carcinosarcoma		<50%	No	No	No	Reactive	No	T1a N0	Yes	Yes
18	MO	230111	No	No	No	Oblong	Regular	7mm	Homogenous	No	No	No	No	None	Ia	Yes	Endometrioid adenocarcinoma	Grade I	<50%	No	No	No	Reactive	No	T1a N0	Yes	Yes
19	SR	799955	No	No	No	Oblong	Regular	4mm	Homogenous	No	No	Yes	Yes	None	Ia	Yes	Endometrioid adenocarcinoma	Grade II	<50%	No	No	No	Reactive	No	T1a N0	Yes	Yes
20	BK	764043	No	No	No	nphnodal m	Lobulated	49mm	Intermediate	Yes	Yes	No	No	None	IIIc1	No, Not fit for surgery											
21	MK	828457	No	No	No	Oblong	Regular	4mm	Homogenous	No	No	Yes	No	None	Ia	Yes	Endometrioid adenocarcinoma	Grade I	<50%	No	No	No	Reactive	No	T1a N0	Yes	Yes
22	SD	854142	No	No	No	Oblong	Regular	4mm	Homogenous	No	No	No	No	None	Ib	Yes	Endometrioid adenocarcinoma	Grade I	<50%	No	No	No	Reactive	No	T1a N0	No	No, myometrial invasion
23	SK	866010	No	No	No	Oblong	Regular	5mm	Homogenous	No	No	Yes	No	None	Ia	Yes	Endometrioid adenocarcinoma	Grade II	<50%	No	No	No	Reactive	No	T1a N0	Yes	Yes
24	UK	866165	No	No	No	Oblong	Regular	7mm	Homogenous	No	No	No	Yes	None	Ia	Yes	Carcinosarcoma		<50%	No	No	No	Reactive	No	T1a N0	Yes	Yes
25	SG	203188	No	No	No	Oblong	Regular	8mm	Homogenous	No	No	Yes	No	None	Ib	No, Surgery refused											
26	PPK	884052	No	No	No	Oblong	Regular	7mm	Homogenous	No	No	Yes	No	Bilateral ovarian lesions likely fibromas	Ia	Yes	Endometrioid adenocarcinoma	Grade II	<50%	No	No	No	Reactive	No	T1a N0	Yes	Yes
27	JK	891201	No	No	No	Oblong	Regular	5mm	Homogenous	No	No	No	No	None	Ia	Yes	Endometrioid adenocarcinoma	Grade I	>50%	No	No	No	Reactive	No	T1b N0	No	No, myometrial invasion
28	KR	904457	No	No	No	Oblong	Regular	7mm	Homogenous	No	No	Yes	No	None	Ib	Yes	Endometrioid adenocarcinoma	Grade I	>50%	No	No	No	Reactive	No	T1b N0	Yes	Yes
29	PK	914451	No	No	No	Oblong	Regular	4mm	Homogenous	No	No	Yes	No	None	Ia	Yes	Adenocarcinoma, NOS		<50%	No	No	No	Reactive	No	T1a N0	Yes	Yes
30	AR	928792	No	No	No	nphnodal m	Lobulated	37mm	Intermediate	Yes	Yes	No	No	Right tubo-ovarian abscess	IIIc1	No, Not fit for surgery											
31	NI	39758	Yes	No	No	Round	Irregular	12mm	Homogenous	No	Yes	Yes	No	Bilateral hematosalpinx with nodularity on left side	IIIc1	Yes	Endometrioid adenocarcinoma	Grade III	>50%	No	Yes	No	Yes	Yes	T3a N1	Yes	Yes
32	BR	928566	No	No	No	Oblong	Regular	6mm	Homogenous	No	No	Yes	No	None	Ia	Yes	Endometrioid adenocarcinoma	Grade I	<50%	No	No	No	Reactive	No	T1a N0	Yes	Yes
33	AS	932317	No	No	No	Oblong	Regular	8mm	Homogenous	No	No	No	No	Right ovarian endometrioma and left ovarian cyst	Ib	Yes	Endometrioid adenocarcinoma	Grade I	>50%	No	No	No	Reactive	No	T1b N0	Yes	Yes
34	KK	6742	No	No	No	Oblong	Regular	7mm	Homogenous	No	No	Yes	No	None	Ia	Yes	Carcinosarcoma		<50%	No	No	No	Reactive	No	T1a N0	Yes	Yes
35	SG	963647	No	No	Yes	Oblong	Regular	6mm	Homogenous	No	No	No	No	None	IVa	No, Inoperable											
36	BK	50007	No	No	No	Oblong	Regular	11mm	Homogenous	No	No	No	No	Bilateral hydrosalpinx	Ib	No, Surgery refused											

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Date 9/9/19

The Principal,
DMC, Ludhiana.

Subject: **Approval of Plan of Thesis.**

This is to inform you that the Faculty of Medical Sciences in its meeting held on 29.05.2019 has approved the plan of thesis of **Balpreet Kaur**, a student of your college for **MD Radio-Diagnosis** along with the names of Supervisor/Co-Supervisor as under:-

Topic Plan of Thesis

Role of mri in staging of endometrial carcinoma

Supervisor
Dr. Archana Ahluwalia
Prof.,
Dept. of Radio-Diagonsis,
DMCH, Ludhiana.

Co-Supervisor
Dr. Ashima Taneja
Prof. & Head,
Dept. of Obst. & Gynae.,
DMCH, Ludhiana.

Dr. Kamini Gupta
Prof.,
Dept. of Radio-Diagnosis,
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The student has to submit the four copies of thesis (along with PDF format) , to the Controller of Examinations, BFUHS, Faridkot, at least six months before the commencement of theory examination, if he/she is otherwise eligible to take the examination. He /She must directed to attach a photocopy of this letter with the forwarding letter while submitting thesis to the University along with the letter of approval of University for change of supervisor/Co-Supervisor, change of topic,(if any).

S P Singh

Dr. S P Singh MS(Oph)
Controller of Examinations

Note :

1. *If any discrepancy found regarding topic of thesis or Supervisor/Co-Supervisor, inform undersigned within one month after issue of this letter.*
2. *The student may submit the thesis as per the schedule already conveyed i.e for May/June examination 30th Nov of the preceding the year of examination and for Nov/Dec examinations 31st May of the year of examination.*

ROLE OF MRI IN STAGING OF ENDOMETRIAL CARCINOMA

THESIS PROPOSAL

FOR APPROVAL OF SUBJECT OF THESIS TO BE SUBMITTED IN

PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

MD

In

RADIODIAGNOSIS

OF THE

BABA FARID UNIVERSITY OF HEALTH SCIENCES

FARIDKOT

December, 2018

Dr. Balpreet Kaur

DEPARTMENT OF RADIODIAGNOSIS
DAYANAND MEDICAL COLLEGE AND HOSPITAL
LUDHIANA

ABSTRACT OF PLAN OF THESIS

Title	Role of MRI in Staging of Endometrial Carcinoma
For the degree of	MD (Radiodiagnosis)
Name of the candidate	Dr. Balpreet Kaur
Supervisor	Dr. Archana Ahluwalia, Professor, Department of Radiodiagnosis, DMCH, Ludhiana
Co-supervisor(s)	Dr. Ashima Taneja, Professor and Head, Department of Obstetrics and Gynaecology, DMCH, Ludhiana Dr. Kamini Gupta, Professor, Department of Radiodiagnosis, DMCH, Ludhiana
Institution	Dayanand Medical College and Hospital, Ludhiana
University	Baba Farid University of Health Sciences, Faridkot

Introduction: Endometrial cancer is the fourth most common malignancy in females and the most common malignancy of the female reproductive tract worldwide. Peak incidence is at around the 6th decade. The most common clinical presentation is post- menopausal bleeding. Adenocarcinomas account for 90% of endometrial neoplasms. Endometrial carcinoma is staged with the International Federation of Gynecology and Obstetrics (FIGO) system. Most tumours (~80%) present as stage I disease. A 5-year survival rate of 96% has been reported for stage I endometrial carcinoma patients and 17% for stage IV patients.

Aim of Study: 1. To stage endometrial carcinoma on MR imaging

2. To assess the role of advanced MR imaging sequences (DCE and DWI) for evaluation of myometrial invasion in patients with endometrial carcinoma.

3. To correlate the results with intra-operative findings and final histopathological examination wherever possible.

Materials & Methods: A prospective study will be done on patients of biopsy proven endometrial carcinoma referred for pelvic MRI to the Department of Radio-diagnosis, Dayanand Medical College and Hospital, Ludhiana over a period of 1.5 years.

Clinical Significance: The pattern of locoregional spread of the disease affects survival and hence treatment protocol. Preoperative information about depth of myometrial invasion and histologic grade is essential in tailoring the surgical approach for these patients. The purpose of this study is to assess the added advantage of DWI and DCE MRI to stage the histopathologically proven cases to offer them the best treatment as per the stage.

Keywords: Dynamic contrast enhanced MRI, Diffusion weighted imaging, Myometrial Invasion, Endometrial carcinoma, Local staging.

Balpreet Kaur

(Signature)	(Signature)	(Signature)	(Signature)	(Signature)
Candidate	Co-supervisor	Co-supervisor	Supervisor	Principal

CERTIFICATE OF FACILITIES AVAILABLE

This is to certify that the facilities for work on the subject of thesis titled **"Role of MRI in Staging of Endometrial Carcinoma"** exist in the Department of Radiodiagnosis, DMC&H, Ludhiana and will be provided to the candidate. We will see that the data being included in the thesis is genuine and is collected by the candidate herself under our supervision and guidance.

Supervisor

Dr. Archana Ahluwalia
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DMCH, Ludhiana

Co-Supervisor

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Place : DMCH, Ludhiana

Date : 5/1/2019

APPROVAL PROFORMA
BY
RESEARCH & ETHICAL COMMITTEE
DAYANAND MEDICAL COLLEGE & HOSPITAL, LUDHIANA

Name of candidate	Dr. Balpreet Kaur
Department	Radiodiagnosis
Topic of Thesis	Role of MRI in Staging of Endometrial Carcinoma
Likely date of appearing in PG examination	May 2021
Date of enrollment	9th May, 2018
Name of Head of Department	Dr. Kavita Saggar
1) Supervisor	Dr. Archana Ahluwalia
2) Co-Supervisor(s)	Dr. Ashima Taneja Dr. Kamini Gupta

Signature of Members of Research Committee with Stamp	**Signature of Members of Ethics Committee with Stamp**
1. HOD Pharmacology	1. HOD Physiology
2. HOD Surgery	2. HOD Pathology
3. HOD Pathology	3. HOD Pharmacology
4. HOD Medicine	4. HOD SPM
5. Dean Academics	5. HOD Medicine
6. Vice Principal	6. HOD Surgery
	7. HOD Obst. & Gynae.
	8. Legal Expert
	9. Secretary, IEC
	10. Dean Academics
	11. Vice Principal
	12. Principal

Approved: Yes / No

Chairperson
Research Committee

Chairperson
Research Committee

Approved: Yes / ~~No~~

Chairperson
Ethics Committee

Chairperson
Ethics Committee

BABA FARID UNIVERSITY OF HEALTH SCIENCES, FARIDKOT

PROFORMA FOR REGISTRATION OF SUBJECT FOR DISSERTATION

1	NAME OF THE CANDIDATE AND ADDRESS	Balpreet Kaur VPO - Maksudra , Tehsil - Payal, District - Ludhiana, 141416
2	NAME OF THE INSTITUTE	Dayanand Medical College and Hospital, Ludhiana
3	COURSE OF STUDY AND SUBJECT	M.D. Radiodiagnosis
4	DATE OF ADMISSION OF COURSE	9th May 2018
5	TITLE OF THE TOPIC	Role of MRI in Staging of Endometrial Carcinoma

6. BRIEF RESUME OF THE INTENDED WORK

6.1 NEED FOR THE STUDY

Endometrial carcinoma is the fourth most common malignancy in females and the most common malignancy of the female reproductive tract worldwide.[1,2] Peak incidence is at around the 6th decade. The most common clinical presentation is post- menopausal bleeding.[3] Adenocarcinomas account for 90% of endometrial neoplasms, the other histologic types include adenocarcinoma with squamous cell differentiation, clear cell, papillary, serous and adeno-squamous carcinoma.[4,5]

Endometrial carcinoma is associated with lifestyle disorders presently epidemic world over, with obesity, hypertension, diabetes mellitus all associated with increased risk of malignancy. Other risk factors include prolonged oestrogen exposure in form of early menarche or delayed menopause, nulliparity, old age, hormone replacement therapy, tamoxifen and familial cancer syndromes such as HNPCC.[6]

Definitive diagnosis of endometrial carcinoma is generally made via endometrial biopsy or dilatation and curettage. Presurgical staging helps to determine the extent of surgery, such as lymphadenectomy, that should be performed. For example, patients with stage IA endometrial carcinoma display nodal metastases in less than 1% of cases, and these patients require only simple hysterectomy. However, patients with endometrial carcinoma that has advanced beyond stage IB require pelvic lymph node dissection and other therapies.[7]

Prognosis depends on a number of factors, including stage, depth of myometrial invasion, lympho-vascular invasion, histologic grade, and nodal status. Depth of myometrial invasion is the most important morphologic prognostic factor and correlates with tumor grade, presence of lymph node metastases, and overall patient survival.[8]

Endometrial carcinoma is staged with the International Federation of Gynecology and Obstetrics (FIGO) system. Most tumours (~80%) present as stage I disease. The mean 5-year survival rate for stage I is 85%, for stage II is 70%, for stage III is 50%, and for stage IV is 18%.[8]

T2-weighted imaging (T2WI) can be used to identify the depth of myometrial invasion. In addition, T2WI with or without contrast-enhanced MRI (CE-MRI) can be used to stage endometrial carcinoma.[9] By providing information on extracellular-space tortuosity, tissue cellularity, and the integrity of cellular membranes, DW imaging has potential roles in distinguishing cancerous from normal tissues, determining lesion aggressiveness, and monitoring response to therapy.[10] MR imaging can also allow accurate assessment of more advanced disease such as cervical stromal invasion or adnexal involvement. Additional information from an MR imaging staging examination (e.g., uterine size, tumor volume, presence of ascites or adnexal disease) may help determine whether the surgical approach should be transabdominal, transvaginal, or laparoscopic.

Diffusion-weighted and dynamic multiphase contrast medium - enhanced MR imaging sequences have been shown to improve the accuracy of MR imaging in assessing the depth of myometrial invasion. The diagnostic accuracy of conventional MR imaging ranges from 55% to 77%.[9] Dynamic contrast-

enhanced images, when read together with T2-weighted images, have a diagnostic accuracy of 85% to 98% for assessing myometrial invasion.[11] The diagnostic accuracy of diffusion-weighted MR imaging for assessing myometrial invasion ranges from 62% to 90%.[12]

Endometrial carcinoma is isointense relative to hypointense normal endometrium on unenhanced T1-weighted images and most commonly shows heterogeneous intermediate signal intensity relative to hyperintense normal endometrium on T2-weighted image.[5,13] Endometrial tumors enhance earlier than does normal endometrium after the administration of intravenous contrast medium. Maximum contrast between hyperintense myometrium and hypointense endometrial tumor occurs 50–120 seconds after contrast medium administration, and this is the most important phase for accurate assessment of the depth of myometrial invasion.[14] Endometrial carcinoma exhibits impeded diffusion compared with surrounding tissue, manifesting with high signal intensity on diffusion-weighted MR images and low signal intensity on ADC maps.[12,15]

6.2 REVIEW OF LITERATURE

The staging of endometrial carcinoma is done based on revised (2009) International Federation of Gynecology and Obstetrics System [FIGO] [16]

Table 1: Revised surgical FIGO staging (2009) of endometrial carcinoma with corresponding MRI findings[8]

FIGO stage	Pathological findings	MRI findings
I	Tumor confined to corpus uteri	
Ia	Tumor limited to the endometrium or invades less than half of the myometrium	The endometrial mass is confined to the endometrium or invades <50% of the myometrial wall with disruption of the JZ
Ib	Tumor invades one-half or more of the myometrium	Mass invades >50% of the myometrium with a preserved stripe of enhancing outer myometrial wall
II	Tumor invades stromal connective tissue of cervix but does not extend beyond uterus**	Disruption of the low-signal intensity inner cervical stroma (T2) Disruption of the cervical epithelium enhancement (cervical epithelium T1)
III a	Tumor involves serosa and/or adnexa (direct extension or metastasis)	Disruption of continuity of the outer myometrium or presence of nodules on the peritoneal surface or adnexa
III b	Vaginal involvement (direct extension or metastasis) or parametrial involvement	Tumor extension into upper vagina and/or parametrium
IIIC1	Regional LN metastasis to pelvic nodes	Enlarged pelvic LN (cut-off value: >10 mm for short-axis diameter)
IIIC2	Regional LN metastasis to para aortic LN, with or without positive pelvic LN	Enlarged para-aortic LN (cut-off value: >10 mm for short-axis diameter)
IV a	Tumor invades bladder mucosa and/or bowel mucosa	Tumor extension into bladder/rectum with disruption of the hypointense signal of bladder or rectal wall
IV b	Distant metastases, including intra-abdominal metastases and/or inguinal LN	Intraperitoneal metastases in peritoneum or omentum. Distant (hematogeneous) metastases to lung, bones or liver. Distant LN metastases

MRI=Magnetic resonance imaging; FIGO=International Federation of Gynecology and Obstetrics; LN=Lymph node

Stage I tumours are treated with transabdominal hysterectomy with resection of bilateral fallopian tubes and ovaries. In cases with cervical stromal invasion (stage II), radical surgery is performed. Stage III or IV is managed with surgical debulking of the metastasis and the primary malignant mass, with chemoradiotherapy.[16]

Beddy et al (2012) compared the diagnostic performance of diffusion weighted (DW) magnetic resonance (MR) imaging with that of dynamic contrast enhanced (DCE) MR imaging in evaluating the depth of myometrial invasion and overall stage in patients with endometrial cancer. This retrospective study was conducted on 48 women with endometrial carcinoma who underwent preoperative MR imaging. Two radiologists independently interpreted the depth of myometrial invasion, overall stage, and presence of pitfalls associated with inaccurate assessment of myometrial invasion at T1- and T2-weighted imaging, DW MR imaging, and DCE MR imaging. The diagnostic accuracy, sensitivity and specificity for DW MR imaging was 90%, 84% and 100% and for DCE MR imaging was 71%, 61%, and 88% respectively. The study concluded that DW MR imaging has superior diagnostic accuracy in the assessment of myometrial invasion and significantly higher staging accuracy compared with DCE MR imaging.[17]

Andreano et al (2014) compared the diagnostic accuracy of dynamic contrast-enhanced (DCE) and diffusion-weighted (DW) MR imaging in detecting deep myometrial invasion in endometrial cancer, using surgical-pathological staging as reference standard. Meta-analysis of nine studies in 442 patients was done. Pooled sensitivity of DW and DCE was 0.86 and specificity did not significantly differ ($p = 0.16$) between the two sequences (DW = 0.86 and DCE = 0.82). The meta-analysis concluded that MR imaging has a high sensitivity and specificity in evaluating deep myometrial invasion and that they did not vary significantly between DWI and DCE imaging and thus DWI can be used as an alternative to contrast enhanced imaging for evaluation of myometrial invasion.[18]

Zheng L et al (2015) compared dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI) with T2-weighted imaging (T2WI) for the preoperative staging of early endometrial carcinoma. This retrospective study included 22 subjects with early endometrial carcinoma who underwent 3.0 T MRI examination prior to hysterectomy. Revised International Federation of Gynecology and Obstetrics surgical staging guidelines (2009) were used as the reference standard. The sensitivity, specificity, PPV, NPV, and accuracy of DCE-MRI for preoperative staging were 100%, 62.5%, 82.4%, 100% and 86.4% and those for T2WI were 85.7%, 75%, 85.7%, 75% and 81.8% respectively. The study concluded that DCE-MRI is more sensitive but less specific than T2WI for the preoperative staging of early endometrial carcinoma. DCE-MRI can serve as a useful and reliable tool for the preoperative assessment of endometrial carcinoma.[19]

Takeuchi et al (2017) compared the diagnostic ability of reduced field-of-vision (FOV) diffusion-weighted (DW) magnetic resonance (MR) imaging with that of three-dimensional (3D) dynamic contrast-enhanced (DCE) MR imaging in evaluating the depth of myometrial invasion in patients with endometrial cancer. 25 women with surgically proven endometrial cancer were retrospectively evaluated. The depth of myometrial invasion on MR imaging was correlated with surgical pathology results. The depth of myometrial invasion could be accurately evaluated in 68% of the cases for T2-weighted imaging, 92% for DCE MR imaging, and 96% for reduced FOV DW imaging. The study concluded that the addition of reduced FOV DW imaging may improve the staging accuracy of MR imaging for endometrial cancer in assessing the depth of myometrial invasion. Especially, reduced FOV DW

imaging has an advantage in assessing the depth of myometrial invasion for patients with coexisting adenomyosis. Reduced FOV DW imaging can be an alternative to DCE MR imaging in evaluating myometrial invasion of endometrial cancer without the use of contrast medium.[20]

6.3 AIMS AND OBJECTIVES OF THE STUDY

1. To stage endometrial carcinoma on MR imaging.
2. To assess the role of advanced MR imaging sequences (DCE and DWI) for evaluation of myometrial invasion in patients with endometrial carcinoma.
3. To correlate the results with intra-operative findings and final histopathological examination wherever possible.

7. MATERIALS AND METHODS

7.1 Source of Data

A prospective study on patients of biopsy proven endometrial carcinoma referred for pelvic MRI to the Department of Radio-diagnosis, Dayanand Medical College and Hospital, Ludhiana over a period of 1.5 years from 1st November 2018 to 30th April 2020.

7.2 METHOD OF COLLECTION OF DATA

This prospective study will be carried out on female patients with diagnosed endometrial carcinoma on histopathology. Patients will be subjected to a multiplanar, multi sequential MRI scan of pelvis on a MAGNETOM SKYRA 48 Channel 3 Tesla MR Machine by Siemens, Germany. Written informed consent will be obtained from each patient and relevant detailed history will be elicited from all patients. Procedure will be explained to patient in his/her vernacular language to allay the fear and anxiety. After definitive treatment of disease with hysterectomy ± local resection, correlation of staging will be done with histopathology report.

INCLUSION CRITERIA

- All patients with biopsy proven endometrial carcinoma.

EXCLUSION CRITERIA

- Any contraindications to MRI (cardiac pacemakers, prosthetic heart valves, cochlear implants or claustrophobia).
- Any contraindications to contrast administration (estimated glomerular filtration rate < 30 ml/min/1.73m^2 in patients undergoing DCE MR Imaging).
- Patients who do not consent to be a part of the study.

MAGNETIC RESONANCE IMAGING PROTOCOL:

All patients will be undergo a multiplanar, multi sequential MRI scan of pelvis on a MAGNETOM SKYRA 48 Channel 3 Tesla MR Scanner by Siemens, Germany.

MR Imaging sequences will include T2 Sagittal, T1 Axial, T2 Axial, T1 Fat sat, T2 Coronal, Diffusion Weighted Imaging (DWI), Dynamic Contrast Enhanced (DCE) MR Imaging, T1 post contrast images and STIR in axial plane uptil aortic bifurcation.

DWI provides information about tissue cellularity and integrity of cellular membranes. At a fundamental level, DWI provides information on the random (Brownian) motion of water molecules in tissues. DCE-MRI involves the acquisition of sequential images during the passage of a contrast agent through a particular tissue of interest. Dynamic imaging can depict the distribution of this agent by measuring variations in vessel and tissue enhancement over time.

MR SYSTEMS AND SCANNING METHODS

Sequences	Localiser	T2 Sagittal	T1 Axial	T2 Axial	T1 Fat sat Axial	T2 Coronal	DWI	DCE	T1 PC Axial	T1 PC Coronal	T1 PC Sagittal
Acquisition Time	0:25	3:29	2:55	2:47	3:25	2:44	3:22	0:15	3:25	3:35	3:35
Orientation	Trans versal	Sagittal	Axial	Axial	Axial	Coronal	Axial	Axial	Axial	Coronal	Sagittal
Resolution Matrix	179 x 256	269 x 384	256 x 320	269 x 384	224 x 320	269 x 384	114 x 114	195 x 320	224 x 320	224 x 320	224 x 320
Number of Slices	9	25	25	25	25	25	25	80	25	25	25
FoV Read (mm)	420	230	220	220	220	230	220	350	220	220	220
FoV Phase (%)	100	100	100	100	100	100	100	81.3	100	100	100
Slice Thickness (mm)	7.0	3.0	3.0	3.0	3.0	3.0	3.0	1.2	3.5	3.5	3.5
Slice Gap (mm)	7.0	3.1	2.1	2.1	2.1	2.1	2.1	20%	2.4	2.8	2.8
Repetition Time (msec)	1000	2800	680	3100	60	2800	4000	3.42	600	630	630
Echo Time (msec)	89	87	18	89	20	87	64	1.24	20	20	20
Flip Angle (deg)	160	180	154	180	160	175	-	9	160	160	160
Fat Suppression	None	None	None	None	Fat sat	None	SPAIR	Q-fat sat	Fat sat	Fat sat	Fat sat
Flow Compensation	No	No	Read	Slice	No	No	-	-	No	No	No

STUDY DESIGN

This is a longitudinal prospective study.

STATISTICAL ANALYSIS:

Data will be described in terms of range; mean ±standard deviation (± SD), median, frequencies (number of cases) and relative frequencies (percentages) as appropriate. Sensitivity, specificity, positive and negative predictive values and accuracy of method and its confidence interval (95% CI) will be also calculated. A probability value (*p* value) less than 0.05 was considered statistically significant. All statistical calculations will be done using SPSS (Statistical Package for the Social Science) SPSS 21 version statistical program for Microsoft Windows.

OUTCOME:

MRI will be performed in the patients of biopsy proven endometrial carcinoma and evaluation of myometrial invasion depth and staging of carcinoma will be done which will help in appropriate treatment and surgical planning, improving the overall prognosis.

7.3 DOES THE STUDY REQUIRE ANY INVESTIGATIONS OR INTERVENTIONS TO BE CONDUCTED ON PATIENTS OR OTHER HUMANS OR ANIMALS? IF SO, PLEASE DESCRIBE BRIEFLY.

No

7.4 HAS ETHICAL CLEARANCE BEEN OBTAINED FROM YOUR INSTITUTION IN CASE OF 7.3?

Attached herewith

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PROFORMA

S. No

Date: MRI regd. No.:

Name: Age/Sex:

MRD No.: Contact no.:

Address:

Height (cm): Weight (kg): BMI:

Co-Morbidity: 1) Diabetes 2) Hypertension 3) CAD 4) Others

History of: Hormone Replacement Therapy Yes No

PCOD Yes No

Carcinoma in Family Yes No

Marital Status: 1) Single 2) Married 3) Widowed 4) Divorced

Number of children and H/o breast feeding :

Menopausal Status: 1) Premenopausal 2) Postmenopausal

3) Perimenopausal

History of prior pelvic radiation therapy:

Presenting Complaints:

1) Abnormal vaginal bleeding

2) Post-menopausal bleeding

3) Others

4) Incidentally detected (mode of detection)

Signature of Candidate **Signature of Supervisor**

EXAMINATION

1) General Physical Examination:

2) Pelvic Examination:

3) Lab Investigations:

4) Ultrasound Findings:

5) Malignancy diagnosed first: Date:

Modality of Diagnosis: Endocervical Curettage or Other

Histopathological Examination Report:

Signature of Candidate **Signature of Supervisor**

MRI FINDINGS

	T1 Weighted	T2 Weighted	Contrast Enhanced Images	DWI
Intracavitary Tumour	Hypo/hyper	Hyper/hypo	Enhancement / Non-Enhancing	Hyperintense with hypointense on ADC
Junctional Zone	Intact / non intact	Intact / non intact	Intact / non intact	Hyperintense with hypointense on ADC
Deep Myometrium	Invaded/ non invaded	Invaded/ non invaded	Invaded/ non invaded	Hyperintense with hypointense on ADC
Cervix	Invaded/ non invaded	Invaded/ non invaded	Invaded/ non invaded	Hyperintense with hypointense on ADC
Lymph Nodes **1. Parametrium** **2. External iliac** **3. Internal iliac** **4. Para aortic**				

Signature of Candidate **Signature of Supervisor**

	ROI 1 Intracavitary Tumour	ROI 2 Superficial myometrial invasion at maximum tumour cross section	ROI 3 Normal superficial myometrium (diametrically opposite to ROI 2)	ROI 4 Deep myometrium at the level of invasion	ROI 5 Normal deep myometrium (diametrically opposite to ROI 4)	
Signal Intensity [SI Max]						
SI 0						
SI Rel						
Wash in Rate						
ADC						

Signature of Candidate

Signature of Supervisor

INTRA - OPERATIVE FINDINGS

HISTOPATHOLOGICAL CORRELATION

Gross pathological findings	Tumour confined to endometrium Superficial myometrial invasion Deep myometrial invasion Cervical invasion	
Histopathological findings	Tumour confined to endometrium Superficial myometrial invasion Deep myometrial invasion Cervical invasion	

Pathology Type 1 [Endometroid] Type 2 [Serous/clear cell/undifferentiated] Others specify		
Lymph Node Metastasis	Yes/No	
Final FIGO Stage	I a/b II III a/b/c IV a/b	

Signature of Candidate

Signature of Supervisor

INFORMED PATIENT CONSENT

Date: _____

I.....D/o, W/o, S/o..... .....am willing to participate in the study **"ROLE OF MRI IN STAGING OF ENDOMETRIAL CARCINOMA"** The procedure with its complications has been explained to me in local vernacular language. I have fully understood that no special tests and extra expenditure in any form, merely for the purpose of thesis is being carried out. I am free to opt out the study any time without assigning any reason.

.....
Signature of the Witness

Name:

.....
Signature of the patient

Signature of Candidate

Signature of Supervisor

मरीज अनुमति फार्म

तिथि _____

मैं _____ पत्नी/पुत्र/पुत्री _____

निवासी _____

इस शोधकार्य **"ROLE OF MRI IN STAGING OF ENDOMETRIAL CARCINOMA"** में भाग लेने के लिए सहमत हूँ। मैं इस शोधकार्य में भाग लेने के लिए अपनी स्वेच्छा से तैयार हूँ। मैं पुष्टि करता/करती हूँ की यह स्वीकृति देने के लिए मुझे कोई आर्थिक प्रलोभन नहीं दिया गया और न ही दबाव डाला गया है। मुझे इस शोधकार्य का उद्देश्य स्पष्ट कर दिया गया है और मुझे यह विश्वास है की यह विज्ञान और मानवता के लाभ के लिए है। मुझे इस शोधकार्य में होने वाले जोखिम के बारे में समझा दिया गया है और मेरी समझ में यह जोखिम बहुत मामुली है।

मैं इस शोधकार्य में भाग लेने के सम्बन्ध में किसी भी समय अपनी अस्वीकृति व्यक्त कर सकता/सकती हूँ और मेरे अस्वीकृति व्यक्त करने का मेरे इलाज पर कोई प्रभाव नहीं पड़ेगा।

_____
गवाह के हस्ताक्षर
नाम:

_____
रोगी के हस्ताक्षर/अंगूठे का निशान
नाम:

_____
अन्वेषक के हस्ताक्षर

_____
विद्यार्थी के हस्ताक्षर

ਮਰੀਜ਼ ਰਜ਼ਾਮੰਦੀ ਫਾਰਮ

ਮਿਤੀ_____

ਮੈ_____ਪਤਨੀ/ਪੁੱਤਰ/ਪੁੱਤਰੀ_____

ਵਾਸੀ _____

"ROLE OF MRI IN STAGING OF ENDOMETRIAL CARCINOMA" ਤੇ ਚਲ ਰਹੀ ਖੋਜ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਲਈ ਰਜ਼ਾਮੰਦ ਹਾਂ। ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਲਈ ਮੈ ਆਪਣੀ ਮਰਜ਼ੀ ਨਾਲ ਤਿਆਰ ਹਾਂ। ਮੈ ਇਹ ਦਸਣਾ ਚਾਹੁੰਦਾ ਹਾਂ/ ਚਾਹੁੰਦੀ ਹਾਂ ਕੇ ਇਹ ਰਜ਼ਾਮੰਦੀ ਦੇਣ ਵਾਸਤੇ ਮੈਨੂ ਕਿਸੇ ਵੀ ਤਰਾਂ ਦਾ ਲੋਭ-ਲਾਲਚ ਨਹੀ ਦਿੱਤਾ ਗਿਆ ਅਤੇ ਨਾ ਹੀ ਕੋਈ ਦਬਾ ਪਾਇਆ ਗਿਆ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਦਾ ਮਨੋਰਥ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ ਅਤੇ ਮੈਨੂ ਇਹ ਭਰੋਸਾ ਦਵਾਇਆ ਗਿਆ ਹੈ ਕੇ ਇਹ ਖੋਜ ਵਿਗਿਆਨ ਅਤੇ ਮਾਨਵਤਾ ਦੀ ਭਲਾਈ ਲਈ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਵਿਚ ਹੋਣ ਵਾਲੇ ਖਤਰੇ ਬਾਰੇ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ ਅਤੇ ਮੈਨੂ ਇਹ ਯਕੀਨ ਹੈ ਕੇ ਇਹ ਖਤਰਾ ਬਹੁਤ ਮਾਮੂਲੀ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਦਾ ਢੰਗ – ਤਰੀਕਾ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ।

ਮੈ ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਬਾਰੇ ਆਪਣੀ ਰਜ਼ਾਮੰਦੀ ਕਿਸੇ ਵੀ ਸਮੇ ਵਾਪਸ ਲੈ ਸਕਦਾ ਹਾਂ/ ਸਕਦੀ ਹਾਂ ਅਤੇ ਮੇਰੀ ਰਜ਼ਾਮੰਦੀ ਵਾਪਸ ਲੈਣ ਦਾ ਮੇਰੇ ਇਲਾਜ ਤੇ ਕੋਈ ਅਸਰ ਨਹੀ ਹੋਵੇਗਾ।

_____ _____

ਗਵਾਹ ਦੇ ਹਸਤਾਖਰ ਮਰੀਜ਼ ਦੇ ਹਸਤਾਖਰ

ਮਿਤੀ_____ ਮਿਤੀ_____

ਪਤਾ _____ ਪਤਾ _____

_____

ਨਿਰੀਖਕ ਦੇ ਹਸਤਾਖਰ

_____

ਸਿਖਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ